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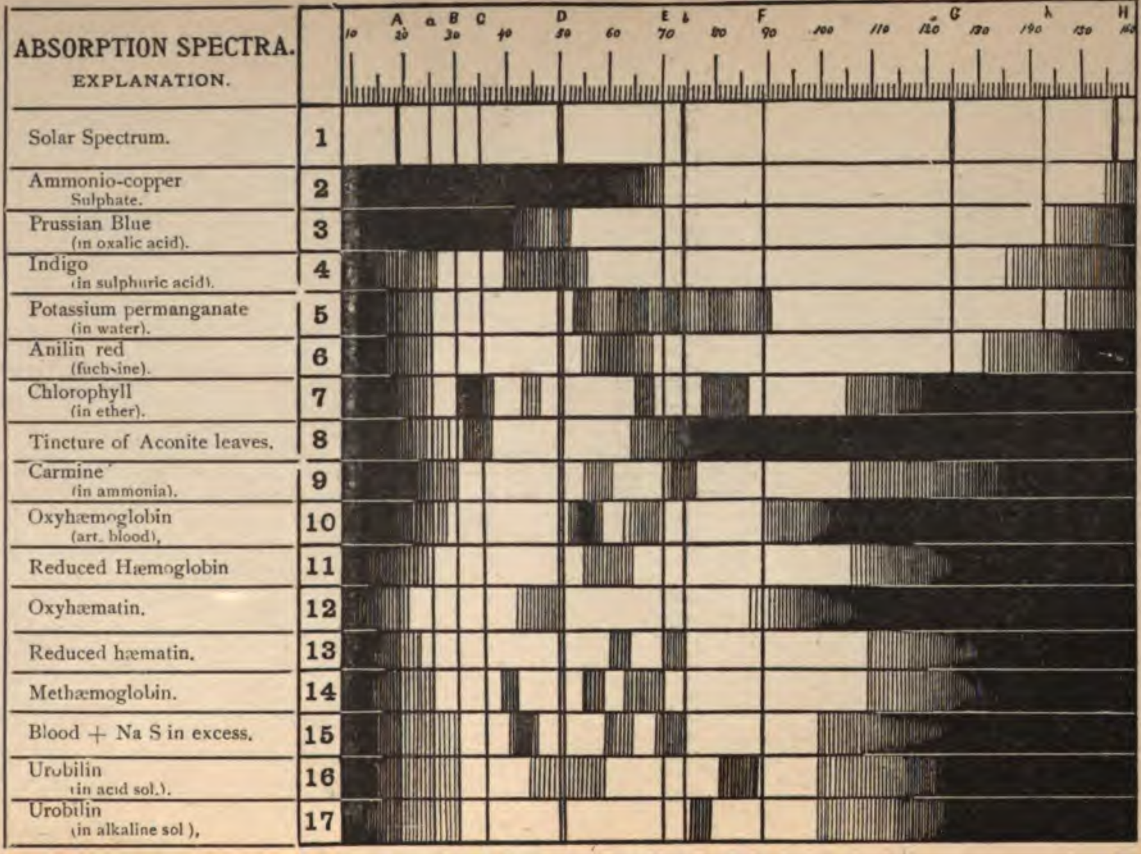

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substances which are unofficial, and not so often met with in pharmacy, and the new remedies, the proposed new spelling has been adopted. It is by no means certain that the reform spelling of chemical terms, as suggested by the American Association for the Advancement of Science, will be accepted by chemists in other English-speaking countries, and as physicians and pharmacists will use the spelling of the Pharmacopœia for at least ten years to come, the author felt justified in this somewhat inconsistent plan of a gradual change to the new spelling, instead of an abrupt one.

That students may become acquainted with the proposed changes, the rules for the new spelling will be found published in the Appendix Teachers are advised to call especial attention to this subject. Especial attention is directed to the useful tables to be found in the Appendix. The tables of equivalent weights and measures and the table of solubilities are especially full and valuable for reference.

The author desires to acknowledge his obligation to various authors whose works he has freely consulted, although the list would be too long to mention here. He is especially indebted to Allen's "Commercial Organic Analysis," Haliburton's "Textbook of Chemical Physiology," Hammersten's "Physiologischen Chemie," Gautier's "Cours de Chimie," Lea's "Chemical Basis of the Human Body," Helbing's "Modern Materia Medica." He is indebted to Leffmann and Beam's "Milk Analysis" and "Water Analysis," for several cuts of apparatus, and to Landois and Stirling's "Human Physiology," from which a number of cuts have been borrowed.

He would also gratefully acknowledge the many suggestions received from teachers and others, who have pointed out typographical and other errors in the third edition.

The reception accorded to the last edition has stimulated the author in the preparation of this, and he hopes that the effort made to make it a useful text-book will meet with approbation.

BROOKLYN, *September, 1895.* E. H. B.

It has been found best, in the author's past experience, to present the elementary theories of Chemistry before entering upon the natural history of the elements and their compounds; and this has been done as clearly and concisely as possible in Part II, giving only what was considered necessary to the proper understanding of all the facts to be presented in the later parts. The subjects of Notation, Nomenclature and Chemical Reactions have been dwelt upon as of first importance to the student.

In Part III, the natural history of the Elements and principal compounds are briefly presented, with their physiological and toxicological bearings.

In Part IV, only those organic compounds are treated with which the physician will be likely to meet. The space that could be given to this part necessitated very short descriptions. The Appendix contains some tables and analyses which will greatly enhance its value as a reference book.

The Chemistry of the tissues and secretions have been omitted, as belonging to the domain of physiological chemistry. It would be impossible to mention all the works upon which the author has drawn for his facts.

Besides the credit given in the text, he wishes to acknowledge his indebtedness especially to Cooke's "Chemical Philosophy," Barker's, Richter's, Witthaus', Fowne's and Rand's text-books; De Watteville's and Jenkins' books on electricity; Prescott's "Proximate Organic Analysis;" Wurtz' "Dict. de Chimie," and "Chemie Biologique;" Charles' "Physiolog. Chem.;" Schorlemmer's, Strecker's and Pinner's "Organic Chemistry," and the "U. S. Pharmacopœia." I would here express my thanks to my friend and assistant, Dr. W. M. Hutchinson, for valuable assistance in preparing the work; also to Mr. W. H. Kent, Ph.D., for similar assistance.

As this work is prepared especially for the medical student, it is to him that I shall trust for its reception, hoping that the labor I have bestowed upon it may help to lessen his.

BROOKLYN, N. Y.
Sept. 1st, 1885.

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Matter exhibits certain properties which are common to all bodies, and which are therefore called the **general properties** of matter; such as indestructibility, impenetrability, divisibility, mobility, gravitation, molecular attraction, chemism and inertia. **Specific properties** are such as are observed in certain bodies only; such as color, hardness, fluidity, transparency, etc.

Matter is Indestructible.—What we generally term destruction is merely a change of form. When wood burns, it is only changed into invisible gases which go off into the air. These gases may be collected, and by analysis we may get back the elements of the wood again. Whatever changes we may produce in a body or mass of matter, we can neither create nor destroy one particle of it; the same weight of matter remains after the change as before.

Matter is Impenetrable.—That is, two portions of matter cannot occupy the same place at the same time. Strictly speaking, this applies only to the ultimate particles of a body. In many phenomena bodies do seem to penetrate each other. For instance, the volume of a mixture of salt and water, or of alcohol and water, is less than the sum of the volumes before they are mixed. In these cases the penetration is only apparent. The penetration of the water by the salt is due to the fact that water, like all other bodies, is porous; that is, it has spaces or interstices between the ultimate particles of which the mass is composed, which are unoccupied by matter, and into which the particles of salt crowd themselves.

Divisibility.—Three divisions of matter are recognized; viz.: **masses, molecules,** and **atoms.**

A **mass** or **body** is any distinct portion of matter appreciable to the senses.

A **molecule** (a little mass) is the smallest particle of matter that can be obtained by subdividing a mass by mechanical or physical means. It may also be defined as the smallest particle of matter that can exist in the free or uncombined state. A molecule of chalk is the smallest particle of chalk that can exist. The molecules are too small to be seen by the aid of the most powerful microscope; their size, however, is approximately known.*

An **atom** is the smallest particle into which any given kind of matter can be divided. The atom is, as yet, a hypothetical body. It is one of the component parts of a molecule, and the smallest particle that can enter into the formation of a molecule.

---

*See page 21.

The density of pure air is 14.44, *i. e.*, air weighs, volume for volume, 14.44 times as much as hydrogen, both gases being weighed at the same temperature and under the same pressure. Density is a very important factor in the study of chemistry, and should be well understood. The sp. gr. of solids may be determined by first weighing the body in the air, and then in water at the required temperature. This is done by suspending the body from one beam of a balance by a thread or fine wire. To weigh in water it is only necessary to place a vessel of water so that the suspended body may hang in the water, or float upon it. **A body which sinks in water displaces a volume of water equal to its own, and loses a weight just equal to the weight of the water displaced.** The loss in the weight of the body when weighed in water, will, therefore, be the weight of its own volume of water. By dividing the weight of the body in air by the loss of weight in water, the sp. gr. is obtained.

Thus, suppose a body weighs 6.200 grms. in air, and 3.100 grms. in water. The loss of weight in water is 6.200 — 3.100 = 3.100 grms., which represents the weight of the water displaced by the body, or the weight of its volume of water. The specific gravity of the body will then be found by dividing its weight in air, or 6.200 grms., by the weight of an equal volume of water, or 3.100 grms., giving a specific gravity of 2.

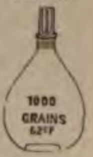
When the body in question will not sink, we may attach a sinker to it, whose weight in air and loss of weight when suspended in water are known. The weight of the body in air is taken, the sinker attached, and both lowered into the water and again weighed. The loss in weight will represent the loss of weight of both the solid and sinker. Deduct the loss in the sinker, and the remainder will represent the weight of a volume of water equal to that of the body in question, whence the specific gravity may be found as above. Bodies which are soluble in water may be suspended in some liquid of known specific gravity, in which they are insoluble.

Thus, let it be desired to obtain the specific gravity of a lump of cane sugar. Suppose it weighs in air 100 grms., and in oil of turpentine (sp. gr. .87) 45.62 grms. Loss = 100 — 45.62 = 54.38 grms. 100 ÷ 54.38 = 1.84 as the sp. gr. referred to turpentine. Multiply this result by .87, the sp. gr. of the turpentine, and we have 1.60 as the true sp. gr. of the sugar.

The sp. gr. of a powder is obtained by partly filling a small flask or bottle with it, and weighing both; the weight of the empty flask, as well as the weight of water it will contain, having been previously ascertained. The flask is then filled up with pure water and again weighed. The difference between the last weight and the first will be the weight of the water in the flask. The difference between this weight and the weight of the water the flask will contain when full, will give the weight of the water displaced by the powder, from which the sp. gr may be obtained as above.

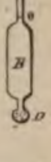
The specific gravity of liquids is obtained by means of the flask above mentioned, called a **picnometer** or **specific gravity flask**, made to contain a certain number of grams or grains of water at a temperature of 60° F., its capacity being marked upon it. (See Fig. 1.) To take the sp. gr. of a liquid, it is only necessary to weigh the flask, filled with the liquid in question brought to the requisite temperature, deduct the weight of the flask, and divide this result by the marked contents of the flask. The specific gravity of liquids is frequently determined also by an instrument called a hydrometer.

FIG. 1.



Hydrometers are long narrow glass or metal tubes, having a chamber near the bottom filled with air, to make it float upright, and a smaller one below this containing enough mercury or small shot to sink it to a convenient depth in water. The hydrometer (see Fig. 2) acts upon the principle of Archimedes, that a body specifically lighter than a liquid sinks in it until it displaces a volume of liquid whose weight is equal to its own, when it becomes stationary. The long narrow stem composing the upper end of the instrument bears a scale indicating the specific gravity by the depth to which the scale sinks in the liquid.

FIG. 2.



Hydrometers are of two kinds: (1) for fluids heavier than water, and (2) for fluids lighter than water. Special hydrometers are constructed for use in certain special liquids, and some with an arbitrary scale giving arbitrary degrees and not specific gravity.

The Twaddell hydrometer, for example, used for liquids heavier than water, is so graduated that the degrees on the scale multiplied by 5 and added to 1000 give the specific gravity compared with water. The **Lactometer** is a hydrometer with a scale specially constructed for the examination of milk. The **Urinometer** is a hydrometer whose scale is made to include the variations in specific gravity found in urine

To determine the specific gravity of liquids with the hydrometer, it is only necessary to drop the instrument into the liquid, which must be at the temperature for which the instrument is constructed, which, in this country, is usually 60° F., and then read off the specific gravity on the scale at the surface of the liquid. (See Appendix for table of sp. gr. of chief liquids of U. S. P.)

Molecular Attraction.—Molecules attract one another, as well as masses. When molecules of the same kind attract one another, they form a homogeneous mass, and the force acting between them is called **cohesion**; when the molecules are unlike it is called **adhesion.** A body on being thrust into water comes out wet, because the water adheres to the body; but if you attempt to pull it apart, cohesion keeps it together.

Chemism.—Atoms attract one another by a force called **chemism** or **chemical affinity.** Chemism holds atoms together to form molecules. It is to the molecule what cohesion is to the mass. Like cohesion it only acts across inappreciable spaces.

Inertia is that property of matter by virtue of which it has no power in itself to change its condition. [This term is often incorrectly limited to the tendency of a body when in motion to continue in motion, and when at rest to remain so.] Chemical or physical changes never take place without the intervention of some external agency.

Extension is that property of matter by virtue of which it occupies space. Its relative degree is obtained by means of weights and measures The system of measures and weights in use in all scientific works is that known as the **metric** or **decimal system.** In most American and English medical books, though not in all, the English system is employed, while all nations of continental Europe use the metric system; so that it is requisite that the student should be familiar with both. The unit of the metric system is the meter. The **meter*** is the length of a platinum bar deposited in the public archives of France, and is 39.37 inches in length The measure was obtained taking $\frac{1}{10000000}$ part of the quadrant of a meridian of the earth, or of the distance from the equator to the pole. The ratio of increase and decrease of the system is decimal, and consequently this system is sometimes known as the **decimal system.** The multiples of all the measures and weights are denoted by Greek numerals, used as prefixes, as will be seen by reference to the tables of weights and measures in the Appendix. Thus, in measures of length we have the meter, **dek**ameter, **hecto**meter and

---

* Also spelled Metre.

The Metric System in Prescriptions.—In prescription writing it will be found convenient to adopt the following rule where the doses have been learned in grains: Make f℥j equal 30 c.c.—*In a two-ounce mixture (60 c.c.) when a teaspoonful is to be given as a dose, write as many grams as there are grains or minims required in each dose.* Thus, suppose it be desired to write for a two-ounce mixture containing 15 grains of potassium bromide in each fʒj; it would be written :—

Grams.
℞. Potass. bromidi, . . . 15|000
Aquæ, ... 60|000 or 60 c.c.
M. Sig.—4 c.c. ter die.

A f℥iij mixture would be written with one and one-half times as many grams as there are grains required in each dose :—

Grams.
℞. Potass. bromidi, . . . 22|500
Aquæ, ... 90|000 or 90 c. c.
M. Sig.—4 c.c. ter die.

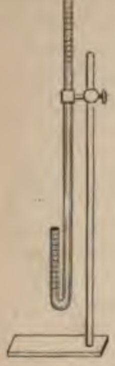
The perpendicular line is used here to occupy the position of the decimal point, and separate grams from milligrams.

It is customary among some pharmacists to weigh all quantities written as above, instead of measuring them. In such cases, it is well to remember that **liquors** have very nearly the same specific gravity as water, excepting those containing the salts of the heavy metals. The **syrups and glycerita** have a sp. gr. of about 1 1/3. The **tinctures** have a sp. gr of about .9. In cases of doubt about the sp. gr., direct the quantity in c.c., when it will be measured.

CHEMICAL PHYSICS.

Three States of Matter.—The same body may exist in three states; as a solid, liquid, or gas. Most solid bodies can be changed into the liquid or gaseous state by the application of heat. For example, when ice is heated, it melts and assumes the liquid form; if we apply heat to the water, it expands, is converted into steam, and tends to escape from the vessel containing it. If we confine the steam, it exerts a strong pressure upon the walls of the vessel, which increases with the temperature. This and other similar facts have led to the adoption of the word **force** to express the nature of heat. The term **heat force** may often be found in works on physics. The capacity which this force possesses of performing work is known one end, is bent upon itself near the other end so as to leave the long arm a little more than 30 inches in length. The long limb is now filled with pure mercury, inverted, and the mercury boiled throughout the entire length, to expel all air. On re-inverting the tube a part of the mercury runs down into the shorter arm until that in the longer stands about 30 inches (760 mm.) above that in the shorter. It is now only necessary to mount the tube and provide some means of measuring the difference in height between the surfaces of the mercury in the two arms. In the instrument represented in Fig. 3 the tube is graduated at two points covering the variations likely to be met with in the barometer. The scale on the long arm is made by measurement from a zero point on the short arm, and may be in inches or millimeters. The short arm is graduated from the zero point both upward and downward. When the surface of the mercury in the short arm is above the zero mark, the distance in inches or mm. is to be deducted from the reading on the long arm; if below the zero mark, the mm. are to be added to the reading. Other methods of reaching the same result are in use.

FIG. 3.



The greater the pressure of the air upon the mercury in the short arm, the higher will it raise the mercury in the longer arm, and *vice versa*.

By means of the barometer we may measure the pressure or tension of the air. The volume of a given mass of gas under a constant pressure varies with the absolute temperature. (See p. 19.)

Law of Mariotte.—This law is stated as follows: **The volume of a confined gas is inversely proportional to the pressure brought to bear upon it**—that is, the less the pressure the greater the volume, and the greater the pressure the less the volume. Stated algebraically this law is: $P : P' :: V' : V$, whence $V' = \frac{PV}{P'}$, in which expression P and P' stand for two different pressures, and V and V' for the corresponding volumes. The pressure exerted upon any mass of gas is usually that of the surrounding atmosphere, and is measured by a barometer. The normal pressure of the air is about 15 lbs. to the square inch, or such that it will support a column of mercury 760 mm. (30 inches) in height. In the expression of pressures, as measured

Now since the fraction $\frac{1}{273}$ when reduced to the decimal form becomes .003665, it is plain that 1 c. c. of any gas at 0° becomes 1.003665 c. c. at 1° C., 1.00733 at 2° C, and 1 + n times .00366 at a temperature of n° C.

Whence the formula may be stated: V' or the new volume, equals V or the known volume, multiplied by $1 + (.00366 \times (t' - t)$ in which t and t' stand for the observed and required temperatures respectively, when t' is greater than t, *i. e.*, when the change of temperature is from a lower to a higher temperature.

When t' is less than t, or when the reduction is from a higher to a lower temperature, the formula becomes $V' = \frac{V}{1 + (.00366\ (t - t')}$.

Since V' and V are common to these two equations, and to the one used in Article 14, for correction of gaseous volumes for changes in pressure, we may combine the equations as follows: $V' = V \times (1 + .00366\,(t' - t)) \times \frac{H}{H'}$, where $(t' - t)$ is a plus quantity, and $V' = \frac{VH}{H'(1 + .0036\,(t' - t))}$ where the reduction is from a higher to a lower temperature. These formulæ may be used for corrections for both temperature and pressure at the same time.

Example.—A given volume of air at 740 mm. and 15° C. measured 452 c.c.; what will it measure at 760 mm. and 0° C.? Substituting, we have—

$$V' = \frac{452 \times 740}{760 \times (1 + (.00366 \times 15))} = 417.2 \text{ c.c.}$$

Standard Temperature and Pressure.—Variations of temperature and pressure produce such important variations in volume, that it is frequently necessary, when comparing observations, to reduce them to some standard temperature and pressure. The **standard temperature** used by most scientific men is 0° C. But 60° F. corresponding to 15.5° C., being about the ordinary temperature of the air, is sometimes found to be more convenient and is frequently used. By **standard conditions of temperature and pressure** are meant 0° C. and 760 mm. pressure.

Constitution of Gases.—Law of Avogadro or Ampère.—This law states that **equal volumes of all bodies in the state of gas, and at the same temperature and pressure, contain the same number of molecules.**

As a necessary deduction from the law it follows: 1st. That **all gaseous molecules occupy the same space.** 2d. That the **weights of equal volumes of any two gases are to each other as the weights of their molecules**; or, in other words, **the specific gravities of any two gases must be to each other as the weights of their molecules.** This law is of vast importance to the chemist, and is considered the basis of most of the modern notions of chemistry. Although it would be out of place here to enter into such a discussion, exhausted of air as possible, containing a vane holding four discs of mica, blackened on one side, and delicately suspended upon a point, so as to revolve with as little friction as possible. On bringing the globe into a strong light, or near a source of heat, it begins to revolve, because of the bombardment of the discs. The dark surface moves in the path of the light.

Diffusion of Gases.—If two gases be brought in contact with one another by inverting one jar over the other, as represented in Fig. 5, the gases will not long remain separate but will quickly mingle so as to make a uniform mixture throughout both jars. This property of gases is called **diffusion**. The diffusion of gases will also take place if they are separated by a porous wall of earthenware, stone, or parchment, by the passage of the gas through the pores. A convenient method of illustrating this phenomenon is to take an unglazed earthenware cup, such as is used in a Bunsen's battery cell, invert it in a funnel provided

FIG. 4.

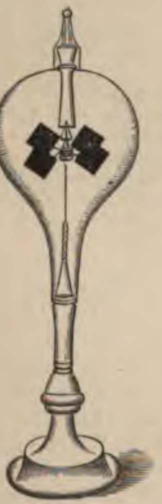


FIG. 5.

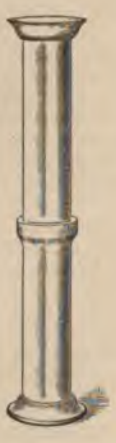
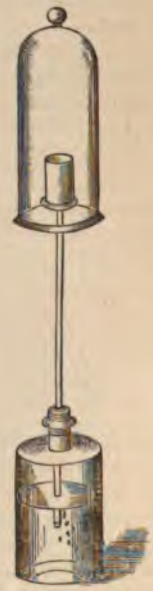


FIG. 6.



with a long stem, and fasten it in place by a paste made of plaster-of-Paris. The lower end of the funnel tube is passed through a perforated cork into a bottle containing water, as shown in the accompanying figure. (See Fig. 6.) On bringing a bell-jar of hydrogen or illuminating gas over the porous cup, the air in the funnel will be forced out below, and may be seen to escape in bubbles through the water.

Graham's Law of Diffusion.—According to this law, **the velocity of diffusion of different gases is inversely proportional to the square roots of their densities.** As an illustration of the truth of this law, we may compare the rates of diffusion of hydrogen and oxygen. By measurement, it has been found that hydrogen diffuses four times faster than oxygen. Their densities are known to be 1 and 16; and the square roots of these numbers are 1 and 4. It will thus be seen that the rates of diffusion are inversely as these last numbers.

The phenomena of diffusion admit of easy explanation on the assumption that the molecules of gases are in a state of rapid motion. Moreover, it is plain, since a given volume of all gases contains the same number of molecules, at the same temperature and pressure, that the moving power of all molecules under these conditions must be the same; for the pressure brought to bear on the gas is balanced by the impact of its molecules, or its elasticity. To produce the same effect against the walls of the vessel, lighter molecules must move faster than the heavier ones, and more impacts occur in a given time. If M be taken as the weight of a given molecule and V its velocity, MV will express its momentum. But the pressure depends not only on the momentum of the molecules, but on the number of blows delivered by each molecule in a given time, which will depend upon the velocity of the molecules. Hence, $MV \times V$ will represent the pressure of the gas. Suppose this pressure be some constant unit of pressure, say the pressure of the air, represented by 1. Then $MV^2 = 1$, and $V^2 = \frac{1}{M}$, or $V = \frac{1}{\sqrt{M}}$. Now M, which represents the weight of the molecule, also, according to Art. 17, represents the density of the gas in question.

The above formula may therefore be written :—

$$V = \frac{1}{\sqrt{D}} \text{ instead of } V = \frac{1}{\sqrt{M}}.$$

For any two gases, the velocities of whose molecules are represented by V and V^1, we should have the following statement :—

$$V : V^1 :: \sqrt{D^1} : \sqrt{D},$$

which, stated in words, becomes : *The velocities of diffusion of any two gases* (the velocities of their molecules) *vary inversely as the square root of their densities*, which is Graham's law. The densities of hydrogen and oxygen are known to be 1 and 16, respectively, and, therefore, the velocities of their molecules must be as the square roots of these numbers, or as 4 to 1; or the molecule of hydrogen must move four times as fast as that of oxygen. The comparative velocities of other molecules may be calculated in the same way, from their densities.

HEAT.

Nature of Heat.—As nearly as we can conceive, the phenomena and sensations to which we apply the term heat are the manifestations to our senses of the motion of the molecules of matter partially discussed in the last sections. Besides producing the sensation of heat, it acts variously on bodies; it boils water, melts iron, makes the metals give out light, electricity, etc.

It was formerly supposed that heat was a form of matter—a subtle fluid which could flow from one part of a body to another, or through the air. We still retain some of the forms of expression used while that theory was held, such as **conduction, convection, absorption, emission, radiation,** etc., the theory itself being entirely abandoned. We now regard heat as a manifestation of one form of molecular motion. The more rapid the motion of the molecules of any given body, the higher the temperature.

Many of the phenomena of heat may be beautifully illustrated by means of a ball attached to an elastic India rubber string held in the hand. The ball may represent the molecule, the string the elastic cohesive force which acts between molecules, and the force applied by the hand to make the ball revolve about it, the force of heat.

The Sources of Heat are the sun, the stars, the interior of the earth, chemical action, and the conversion of chemical or molecular motion into heat. The earth receives but about two thousand millionths of the heat of the sun, and the fixed stars are estimated to furnish about ⅘ as much as the sun. The amount of heat annually received from the sun would melt a layer of ice surrounding the earth 101 feet thick. The internal heat of the earth has some effect upon our temperature, but not a very important one, as the crust of the earth does not conduct heat well. Chemical action is the most important artificial source of heat. When the heat thus produced is intense, and accompanied by light, the bodies are said to burn. In an ordinary fire, the heat produced is due to the chemical action going on between the oxygen of the air, and the carbon and hydrogen of the fuel. Animal heat is largely due to a similar cause—that is, to chemical action going on in the muscles, glands, brain, and, in fact, all the tissues; not, as formerly taught by Liebig, by direct combustion of the food by the oxygen of the air, but by oxidation of the different tissues whenever they are called upon to exercise their functions (See Part VI.)

Mechanical force may be converted into heat, as when the axle of a railroad coach becomes hot, or when the brakes are applied to the wheels, or when a piece of steel strikes a piece of flint. These phenomena may be imitated with the ball and string above mentioned, by allowing some one to strike the ball while it is swinging, so as to drive it faster on its course. This is what takes place when the steel comes in contact with the flint.

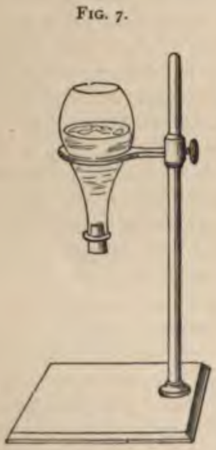
Mechanical Equivalent of Heat.—There is an intimate relationship between heat and mechanical motion. They are capable of being converted, the one into the other. The friction of the match against a roughened surface produces enough heat to ignite it. Heat, on the other hand, is converted into motion by the expansion of steam, which drives the steam engine. It has been determined that a certain amount of heat has its exact equivalent of work. The unit of work is the foot-pound—the power required to raise one pound one foot high; and the unit of heat is the heat necessary to raise one pound of water from 0° to 1° C. This amount of heat, if it could all be made to do mechanical work, would be sufficient to raise 1390 lbs. one foot high; or the thermal unit is equivalent to 1390 foot-pounds. If we adopt as the thermal unit the heat necessary to raise one pound of water from 32° to 33° F., it is equal to 772 foot-pounds.

Effects of Heat.—One of the first effects of heating a body is to expand it. This is the effect of heat upon all bodies, with a few apparent exceptions. Silver iodide is a notable exception to this rule. To understand just what takes place when heat expands a body, let us return to our ball and string (p. 24); the more force we apply to it from the arm, the more rapidly the ball will move; as it does so, the more it stretches the string and the larger the arc it describes. If we apply enough force the string will break, and the ball will fly off into space. (Compare p. 16.)

Melting and Freezing Points.—When heat is applied to the molecules, it drives them faster through their paths and farther apart from one another, until finally the cohesive force is stretched to its utmost and is on the point of breaking; then the body melts and becomes a **liquid,** in which state the two forces are nearly equal, with cohesion slightly predominating. The temperature at which a body, usually solid, passes into a liquid state, is called its **melting point.** If more heat be now applied, the cohesive force (represented by the elastic string above) gives way, the molecules begin to fly off into space, and we say the liquid boils or passes into the **gaseous state.** If the heat is abstracted from a body that ordinarily exists in a liquid state, cohesion more and more overcomes the heat force between the molecules until the body contracts and passes into the solid state. The temperature at which this takes place we call the **freezing point** of the body.

Boiling Point of Liquids.—The temperature at which a liquid in an open vessel gives off vapor rapidly from the whole liquid is constant for that liquid, and is called its **boiling point.** In giving a description of a liquid the boiling point is usually given. The boiling point of water is 100° C. (212° F.), and is nearly constant when boiled in an iron vessel in the open air. It is slightly higher in a glass or other vessel with polished walls, because the steam adheres to such a surface until it becomes a little above that point, or is slightly superheated. The pressure exerted upon the surface of the liquid may cause the temperature of the boiling point to vary, by resisting the expansive force of the molecules and aiding cohesion to keep them together. When considerable pressure is brought to bear upon a boiling liquid, its temperature rises until the tension of the steam overcomes this pressure, and it becomes **superheated.** Conversely, if the pressure be removed or lessened, the temperature at which the liquid will boil is lowered. This may be illustrated by the experiment known as the **culinary paradox,** as follows:—

FIG. 7.



Take a flask of water, and after boiling it vigorously for a few minutes, so that the rising steam may expel most of the air, cork it up with a tightly-fitting cork, when the boiling will cease; remove the lamp and turn the flask bottom upward. (See Fig. 7.) By pouring cold water on the flask the steam is condensed, the pressure is removed from the water, and it boils vigorously. Now, allow the steam to fill the flask above the water, and it again ceases boiling. A dash of cold water will again make it boil. This may be repeated until the water becomes cool enough to be held in the hand with comfort.

The boiling point of water varies, then, with the height of the barometer, or the pressure of the atmosphere upon it. As the height of the barometer diminishes in ascending from the surface of the earth, the boiling point of water must fall. An ascent of about 1080 feet lowers the boiling point of water 1° C. By this means the height of mountains may be determined within a few feet. When a liquid passes off into vapor, it is said to **evaporate.** Evaporation from liquids takes place slowly and imperceptibly at temperatures below their boiling points. In the case of water, for example, there is some evaporation even from the surface of snow and ice. The moisture of the air, from which clouds, rain, snow, dew, etc., are formed, is carried up by this imperceptible evaporation from the ocean, lakes and rivers.

Distillation and Sublimation.—When a liquid is rapidly evaporated and condensed again by means of cold, the process is called **distillation.** When water containing solid matters in solution is evaporated, the solids remain in the vessel while the water only is given off. By reason of this fact we are able to prepare perfectly pure water by distillation. When a mixture of two or more liquids is heated, that having the lowest boiling point begins to evaporate or distil first, leaving the others behind. During the rapid evaporation of a liquid, its temperature remains nearly constant at the boiling point until it is all evaporated. To separate a mixture of liquids having different boiling points, it is only necessary to heat the mixture until that having the lowest boiling point begins to boil, and allow it to remain at that temperature until it has all passed over and been condensed. The condenser is now removed and another attached; the temperature is now raised until another portion of the mixture begins to distil over, and so on until the liquids are separated. The first process seldom effects a perfect separation, owing to some heavier liquids being carried over by the lighter ones; a second or even a third distillation is often necessary. The above process is called **fractional distillation.**

By the term **destructive distillation** is meant a distillation, usually of dry substances, so as to destroy them and obtain liquids or gases; as, for example, the distillation of coal for the purpose of preparing illuminating gas, and liquids to be used for various purposes; and the distillation of wood to prepare vinegar, wood spirit, etc. Distillation is carried on in a retort or still, and the vapor is condensed in a worm or condenser. The retort, or still, is the vessel in which the liquid is heated, and is made of glass, copper, iron, or platinum. (See Figs. 8 and 64.)

The heat is applied to the retort or still until the liquid boils.

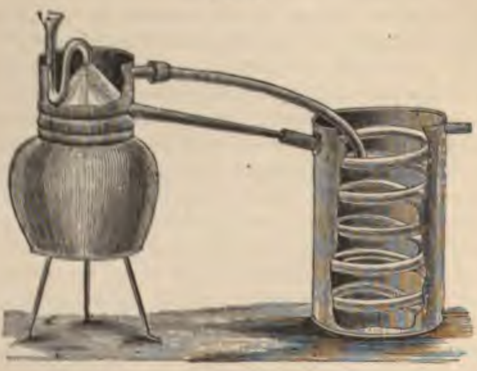
The vapor from the boiling liquid passes through the beak of the retort into the condenser, which is always kept cool by means of cold water.

A few solid bodies when heated do not melt and form liquids, but pass directly into the state of vapor. Such bodies are said to **sublime**, and the process is called **sublimation.**

Iodine, sulphur, camphor, and ammonium chloride, are examples of bodies which may be sublimed, and this process is usually employed for their purification.

Latent Heat.—It is evident that a part of the heat force applied to a body is used up in overcoming the force of cohesion and in expanding the body, and does not appear in the actual moving power of the molecules. In our ball-and-string illustration (p. 24), a part of the force applied to the string by the hand is expended in stretching the string, or finally in breaking it, and does not appear in the moving power of the ball. This force, which is expended in overcoming cohesion, and in keeping the molecules apart, does not appear in the temperature of a body. When air is heated and allowed to expand, about two-sevenths of the heat force is used up in expanding it. If we apply heat to a vessel containing ice, the temperature of the water formed is the same as that of the ice, although a considerable heat has been absorbed in the melting process.

FIG. 8.



When water is boiled in an open vessel it does not rise above 100° C. (212° F.), however hot the fire; it remains at 100° C. until it is all evaporated. What has become of all the heat applied to the water? It has been used to drive the molecules farther apart, and is locked up in the water in the first case, and in the steam in the second. The heat thus expended is called **latent heat.** **It requires heat to convert a solid into a liquid, or a liquid into a gas.** The reverse is equally true, that **heat is given out when a gas becomes a liquid, or a liquid becomes a solid.** Freezing mixtures are based upon this law. A mixture of salt and ice freezes, because the salt melts the ice by its affinity for water; but heat is absorbed by a solid when it becomes a liquid, and is taken up in this case from whatever happens to be in contact with the freezing mixture or vessel containing it. Ice machines operate on the principle that when a liquid evaporates, it absorbs large quantities of heat. A very volatile liquid may be made to evaporate rapidly by placing the vessel containing it under the receiver of an air-pump, and removing the pressure from it by pumping out the vapor as fast as formed. A very low temperature is produced in this way in and about the vessel containing the liquid. Place a few drops of ether upon your hand, and allow it to evaporate, and you will have a very good illustration of the heat absorbed by an evaporating liquid. Mitchell obtained a temperature of—146° F. with ether and solid carbon dioxide. Vatterer produced a temperature of—220 F. with liquid nitrous oxide and carbon disulphide.

Specific Heat.—When equal weights of two given bodies are exposed to the same source of heat, they do not both rise in temperature with the same rapidity—that is, it takes more heat to raise a pound of water from 0° to 1° C. than it does to raise one pound of mercury through the same change of temperature. The relative amount of heat required to raise equal weights of substances through equal degrees of temperature is called their **specific heat.** Water has the highest specific heat of any known substance except hydrogen gas. The unit of specific heat is not everywhere the same. Some use as the unit of heat the heat required to raise 1 pound of water from 32° to 33° F., others from 0° to 1° C. The latter is the one most commonly used, and is called the **thermal unit.** In France the unit is the **calorie,** which is the heat required to raise 1 kilogram of water from 0° to 1° C. 1 Calorie = 2.2 thermal units. 1 thermal unit = 0.45 calories.

Temperature.—From the preceding article it will be seen that the temperature of a body is entirely distinct from the amount of heat it contains. Temperature may be defined as the tendency a body possesses of imparting heat to surrounding bodies. It is this tendency which gives to our senses the impression that the body is **hot** or **cold**; it is, therefore, the measure of its **sensible heat**, or heat that is appreciable to our senses. The heat which a body contains is made up of its sensible heat plus its latent heat. The temperature of a body is increased or diminished by adding to or withdrawing from it sensible heat. As the number and weight of the molecules of a given body are constant, the variations of temperature must mean a variation in the velocity of the moving molecules. In our ball-and-string illustration it will be indicated by the velocity of the ball in its path.

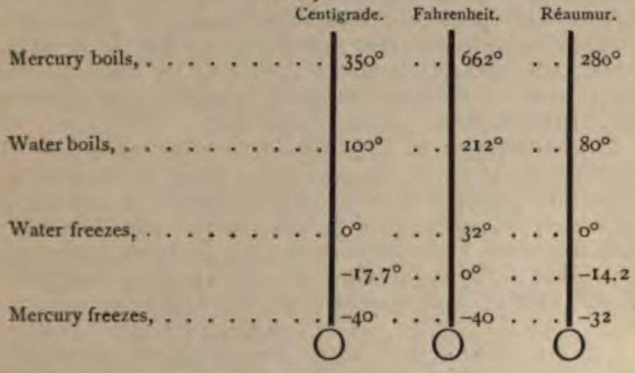
Thermometers.—Temperature is measured by an instrument called a thermometer. Thermometers are usually constructed of a closed glass tube, provided with a bulb at one end, containing a liquid whose expansion or contraction is used to indicate the temperature. It is also provided with a scale to mark the amount of contraction or expansion taking place in the liquid. Liquids are usually chosen, as solids expand too little and gases too much to be convenient. The liquids commonly used are mercury or alcohol; of these the former is most extensively used, because of the long range of temperature between its freezing and boiling points. Pyrometers are instruments for measuring very high temperatures, and are constructed of metal, or fire-clay, whose melting point is very high.

The thermometric scales in common use are the Fahrenheit, Celsius or Centigrade, and Réaumur. The difference in these scales may be seen at a glance by reference to Fig. 9. There are two fixed points in all of them—the temperature of melting ice, and that of the steam from boiling water. These two points must be determined by actual trial on every instrument; these points are marked on the glass with a file or diamond. It then remains only to divide the space between them into a certain number of degrees, according to the scale adopted. In the Centigrade or Celsius, and in the Réaumur, the freezing point of water is marked 0°, while in the Fahrenheit it is marked 32°.

The point at which the mercury rises in the tube when the latter is plunged into steam from boiling water, is marked 100° in the Celsius, 212° in the Fahrenheit, and 80° in the Réaumur. It remains, then, simply to divide the space between these points into 100 equal parts in the first, 180 in the second, and 80 in the third. Chemists generally have adopted the Centigrade scale, although some still adhere to the Fahrenheit, which is in common and almost universal use in this country for unscientific purposes. The Réaumur is not much used in this country, and we shall not use it in this book. It is not difficult to change the readings from one to the other scale.

It will be seen that 100° C. = 180° F., 1° C. = 1.8° F., or 1° C. = $\frac{9}{5}$° F., and 1° F. = $\frac{5}{9}$° C. We must remember, however, that the 0° mark in the Fahrenheit scale is 32 degrees below that of the Celsius; hence, in converting degrees F to degrees C. we must first take from the reading 32°, and reduce only those above the freezing point of water. While in changing degrees C. to F., we must add 32° to the result, to obtain the true reading.

FIG. 9.



Thus, 10° C. = 10 × $\frac{9}{5}$ = 18 + 32 = 50° F.; and 41° F. = 41 − 32 = 9 × $\frac{5}{9}$ = 5° C. Or, multiply degrees C. by $\frac{9}{5}$, and add 32 = degrees F.; and multiply degrees F. by $\frac{5}{9}$ after subtracting 32 = degrees C.

The Centigrade and Fahrenheit degrees will both be given in this book.

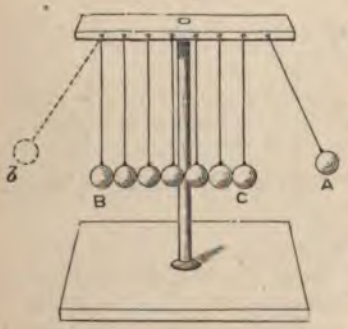
LIGHT.

The second so-called physical force which plays an important part in many chemical phenomena is light. According to the best conception we have of light, it is the effect upon the optic nerve produced by undulations of an exceedingly subtle and highly elastic form of matter, called the **luminiferous ether.** That this ether really exists, pervading the spaces between the molecules of all bodies, and being many million times more elastic than air, and so light that it offers no appreciable resistance to the earth moving 1100 miles a minute through it, is merely a hypothesis. It has been advanced to explain certain well-known facts. That light passes from the sun and stars to the earth, no one can doubt; and yet, without some assumption like the above, we cannot conceive how it does so unless we hold to a former view, which taught that light is in itself a form of matter, without weight, given off by luminous bodies, and able to pass through glass, water, rocks, etc. These properties are contrary to all known laws of ordinary matter, as also are those of the ether assumed in the other theory.

It is believed that undulations may originate in certain motions of molecules or atoms; that these motions or undulations are communicated to the ether and conveyed upon it in the form of waves; and that the movement described by a given particle of ether, is, in the main, an oscillation at right angles or perpendicular to the direction of the ray or beam.

Transmission of Light.—The motion of a ray of light travels along the line of particles very much in the same way that it passes along the line of ivory balls placed in contact on the billiard table, when a ball strikes the end one directly in line with the rest. The motion or impulse passes along the line, but the ball at the opposite end is the only one seen to move. The transmission of force may be illustrated by placing a ruler on the table, holding it firmly in place, with a marble in contact with one end, and with a hard body striking a short quick blow at the other end. The stick, as a whole, does not move, but the jar will be felt to pass under the hand, and the marble will move from its place.

FIG. 10.



A frequent class-room illustration of the transmission of force is that represented in Fig. 10. A number of wood or ivory balls are suspended by cords so that they touch one another when at rest. On raising A to the position represented in the cut, and allowing it to fall against the ball C, none of the balls are seen to move except B, which is carried on to the position *b*. As it returns to strike its neighbor, the ball A is thrown off to a less distance than it was at first carried. The other balls remain at rest, but transmit the force along the line.

Color and Intensity.—It is evident that these oscillations may differ in rapidity or in their amplitude; *i. e.*, comparing them to the movements of a pendulum, they may vibrate rapidly or slowly, and they may swing a long or short distance. Upon the extent and rapidity of these oscillations depend two important differences in the effects of light on the organs of vision; viz., color and brilliancy; the brilliancy depending upon the force of the blows upon the retina, and the color upon the number in a given time. We have an analogous fact in sound. Here we can more easily demonstrate the truth of the fact that the intensity of the sound depends upon the amplitude of the vibrations of the molecules, while the pitch depends upon the number of waves or pulsations which reach the ear in a given time. From well-established data, we are able to calculate the rapidity of the oscillations which produce the different sensations of color, and the corresponding lengths of the ether waves. Some of these results are expressed in the following table:—

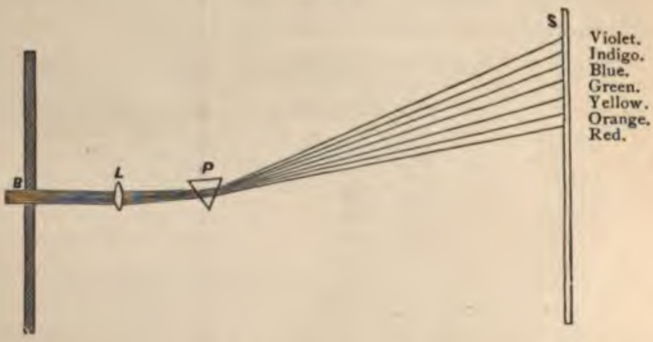
Color.	Length of Waves in Fractions of a Millimeter.	Number of Oscillations in one Second.
Red.	650 millionths.	477,000,000,000,000
Orange.	609 "	506,000,000,000,000
Yellow.	576 "	535,000,000,000,000
Green.	536 "	577,000,000,000,000
Blue.	498 "	622,000,000,000,000
Indigo.	470 "	658,000,000,000,000
Violet.	442 "	699,000,000,000,000

The color of an object depends upon the character of the light it reflects or transmits to the eye. A beam of white light is composed of a variety of different colored lights mingled together, as can be shown by passing it through a prism of glass having an angle of 60°, by which it is decomposed into its component colors. When a body looks red to us, it is because it absorbs or destroys all the oscillations of the white light except those which give us the sensation of redness. If it be blue, only the vibrations that give us the sensation of blue light are reflected. Some bodies and solutions reflect one color, and transmit another. The color transmitted is usually the complement of the one reflected; *i. e.*, if the two lights are mixed together they produce the sensation of white light. If a solution of nickel salt and one of cobalt are cautiously mixed, the color of the one mixes with that of the other so as to form a colorless solution, because the colors are complementary.

The Spectrum.—When a beam of white light is passed through a prism, as represented in Fig. 11, it is not only refracted—that is, bent from its original course, but the colors of which it is composed being unequally bent, are separated from one another. If now we allow them to fall upon a white screen, S, Fig. 11, they produce a series of blending tints upon it, which are called a **spectrum.**

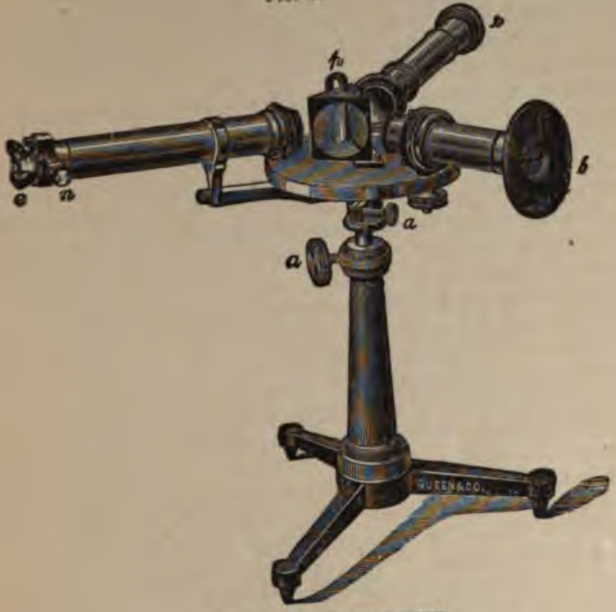
The red rays, which are least bent from their course, are said to be the **least refrangible,** while the violet are the **most refrangible.** Intermediate between these colors we find the orange, yellow, green, blue, and indigo. The prism thus gives us an easy means of analyzing a beam of light, to show the character of the rays producing it. Such observations are usually conducted by means of an instrument called a spectroscope.

FIG. 11.



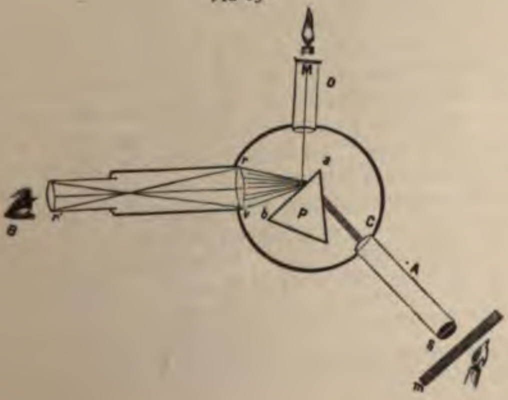
The Spectroscope.—Fig. 13 will illustrate the construction of the spectroscope. The light is received from the source of light, through a very narrow slit (S), regulated by a screw; it passes through the tube (A), called the collimator, and is directed through the prism (P) which may be made of flint glass, or it may be made hollow and filled with bisulphide of carbon. In some instruments there are several flint glass prisms so arranged that the light is made to pass through all of them, so as to secure a wider dispersion of the rays than can be obtained with one prism. The beam of light, after traversing the prisms, is viewed with the telescope at (B). For purposes of comparison, an additional tube (D) is attached, by which another light may be thrown upon the surface of the prism so as to be reflected through the telescope

FIG. 12.



SINGLE PRISM SPECTROSCOPE.

FIG 13..



by the side of the light from (S).* Many instruments now made are so arranged that the ray of light in passing through the prism is not bent from its course, and these are called **direct vision spectroscopes.**

Bright Lines.—When we view **mono-chromatic** light with the spectroscope—that is, a light composed of but one color, we see only a vertical image of the slit at B, and its position will depend upon the refrangibility of that color. If, on the other hand, we illuminate the slit with a light containing several rays of different degrees of refrangibility, we shall see one image for each ray present; and they will be separated from one another by their differences of refrangibility. The same color always appears in the same position with reference to the others. If we look at a solid body, heated till it emits a pure white light, there are so many images spread out on the field of vision, that one overlaps another until there are no dark spaces between them, and thus give a **continuous spectrum**, as it is called. If we place a light before the slit which emits very little light of its own, such as that given by a Bunsen burner, and then put into this flame a little sodium which gives a pure yellow light, we shall see but one image of the slit, and that in the position occupied by the yellow in the continuous spectrum, or the D line in the solar spectrum. If we use lithium instead of sodium, we get one image in the position occupied by the red; if thallium be used, the single image is seen in the position of the green. If we mix the three, we shall see the three images as bright lines, each in its own position—one in the yellow, one in the red, and one in the green. In the best instruments the yellow sodium line appears as two parallel lines. If we illuminate the slit with the vapor of a metal which emits rays of several different degrees of refrangibility, we shall see several images, or bright lines, in different portions of the field. Any given element always emits the same rays under like conditions; hence, by the use of the spectroscope, we may determine by the lines we see in the telescope what element is introduced into the flame of the lamp.

Solar Spectrum—Dark Bands.—If we illuminate the slit with the light of the sun, we see almost a continuous spectrum marked by a number of dark lines, known as "Fraunhofer's lines," the cause of which we shall refer to again.

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* For an explanation of the principle of lenses the student is referred to works on Physics.

The most prominent of these dark lines have been designated by the letters of the alphabet, as will be seen on reference to the solar spectrum in the **frontispiece.** These lines serve as landmarks upon the spectrum, by which we can fix the position of other lines, or by which we can designate the position of any line. The D line, for example, is the most brilliant, and can always be seen in the solar spectrum. This serves as a starting point in mapping the spectrum, or as a guide in focusing or adjusting the telescope.

Spectrum Analysis.—The spectroscope is an important aid to chemical analysis when used with certain precautions, and with certain well-known facts in its use, kept in mind.

The principles upon which spectrum analysis is founded are as follows :—

1st. All bodies, when intensely heated, become luminous.

2d. Solid and liquid bodies, if opaque, emit when heated, first a red light, and as the temperature rises the other colors make their appearance, and mingle with it until all the colors are present and produce white light. If the temperature reaches what is called a blue heat, the blue and violet begin to predominate.

3d. The elementary substances give their characteristic and peculiar light only in the state of gas or vapor. Hence, when we examine the light from any given source, we conclude if the spectrum is continuous, that the heated substance is a liquid or a solid, while if the spectrum is broken, that it is a luminous gas or vapor. From the position of the bright lines, we determine the nature of the substance giving the light. There are, however, a few exceptions to this principle. Under certain conditions, even a gas may give off a light that will give a continuous spectrum.

4th. At the temperature at which gases or vapors become luminous, compound bodies, as a rule, break up into their constituents; *i. e.*, the elemental atoms seem to be dissociated. For this reason little is known of the spectra of compound bodies.

5th. At a high temperature the metallic atoms are much more luminous than the non-metallic with which they are associated. Hence, when we examine the vapor of a metallic salt rendered luminous, the light emitted is so largely that of the dissociated metallic atoms, that, whatever salt of that metal be used, we obtain essentially the spectrum of the metal itself.

6th. If, when the slit of the spectroscope is directed toward a source of white light giving a continuous spectrum, another flame giving a mono-chromatic light from a luminous vapor be interposed between the white light and the slit, a dark image of the slit will appear in the position where the vapor itself would have given a bright line. That is, when the light from a liquid or solid luminous body is made to pass through a luminous vapor, those rays of light which the vapor of itself emits are absorbed. Hence, when we analyze the light of a distant source of light, and observe a continuous spectrum marked by dark lines, we may conclude that it is produced by a solid or liquid luminous body shining through a luminous vapor. This explains the dark lines seen in the solar spectrum. They teach us that the sun is a solid, intensely luminous body, surrounded by a luminous atmosphere.

7th. Many substances in solution absorb certain rays from a beam of white light passed through them, and the portions of the spectrum absorbed are peculiar to each substance. We thus have a means of detecting the presence of a few substances, which cannot be rendered luminous, by passing a white light through the solution suspected to contain them.

Absorption Spectra.—When we wish to observe the spectrum of a liquid, we place it in a glass tube, or, preferably, a vessel having parallel sides, and place this before the slit of the spectroscope. We now throw a strong white light through the solution and into the slit of the instrument. Solutions of **erbium** and **didymium** examined in this way absorb certain portions of the spectrum given by the source of light. The particular portions of light absorbed are peculiar to each, and in these cases the dark bands across the bright spectrum occupy the same positions in which the vapors of these elements give light bands. Absorption bands differ from the dark lines of the solar spectrum, in being broader and not so sharply marked. They are often only a slightly darkened portion of a bright spectrum. Even passing the light through a crystal, in some cases, gives the same result as passing it through its solution.

The use of the spectroscope in medicine and toxicology is chiefly confined to the observation of absorption spectra of various solutions. Some idea of the appearance of such spectra may be obtained by reference to the frontispiece, remembering that the spaces which appear white there, are in practice occupied by the colors of the solar spectrum in their appropriate places.*

Chemical Effects of Light.—If a mixture of pure hydrogen and chlorine gases be prepared in the dark, and kept there, no combination takes place; if the mixture be brought out into a light room, a gradual combination takes place, and hydrochloric acid is the result; if the mixture be placed in the direct rays of the sun, instead of diffused light, the combination takes place with an explosion. The light in this case causes chemical action. The electric light and other intense lights produce the same action. If a piece of white paper wet with a solution of nitrate of silver, be kept in a dark room, no change takes place in it; but if the paper be exposed to a strong light, it begins to grow dark and finally becomes black.

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* See Rosenberg or McMunn on the use of the spectroscope in medicine.

Many chemicals kept in the light are in time sensibly changed. Silver and gold solutions, in presence of organic matter, deposit a part of their metal in the metallic form. Nitric acid becomes slowly yellow from the decomposition produced by the light. A solution of the syrup of the iodide of iron, on exposure to air, becomes brown from decomposition; but on exposure to the direct sunlight it again recombines and returns to the normal green color. The art of photography is based upon the changes produced by light in silver salts, gelatin, etc. Sometimes the change seems to be a true chemical reaction, and in other cases it is a molecular change only.

It has been found that it is not always the luminous part of the ray of light that effects these changes, but that they are chiefly produced by certain invisible rays found most abundantly in and beyond the violet part of the spectrum. From this it has been concluded that the light of the sun, as well as the light from some other sources, contains certain rays having this power to produce chemical changes, but which do not affect the eye to give the sensation of light. This action is known as **actinism**, and the rays producing it are called **actinic rays.**

The heat rays which accompany the light rays in an ordinary beam of light are less refrangible than the latter, and are therefore found principally in the orange, red, and ultra-red portions of the spectrum.

We thus have three kinds of rays in the solar spectrum.

I The heat rays extend from without the red to the line *F* (see frontispiece), being most intense at A or in the red.

II. The light spectrum extends from A to H, being most intense between D and E.

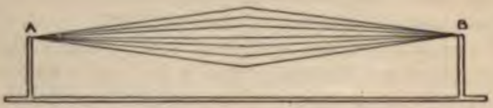
III. The actinic rays found from E to some distance beyond the violet, and being most intense at H.

Polarization of Light.—Ordinary light, according to the wave theory, is due to vibrations of the luminiferous ether occurring in all directions or planes at right angles to the path of the ray.

A ray of light is said to be plane polarized when these vibrations are so changed as to occur only in one plane. This change in the vibrations may be produced by passing the ray of light through certain crystals, such as Iceland spar, selenite, quartz, etc., or by reflection from a glass plate placed at an angle of 35° 25′ to the path of the ray, or from water at an angle of 52° 45′.

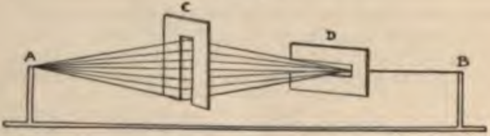
We may illustrate the effect of polarization upon a ray of light, roughly, by a string stretched between two points, A and B, Fig.

FIG. 14.



14. If we touch the string with the finger it is free to vibrate in all directions, up and down, side to side, or in any intervening plane. If now we place over the centre of the string a piece of cardboard, C, Fig. 15, with a long slit cut in it, and then cause

FIG. 15.



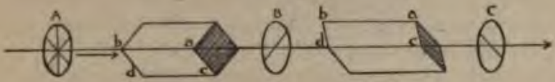
the string to vibrate, the vibrations will be limited to the direction of the length of the slit in the card. This may serve to illustrate the effect of a polarizing crystal upon a ray of light.

If, in this experiment a second piece of cardboard be employed, so held that the slit is in the same position as the first, no interference with the vibration will take place. This cardboard may serve to represent a second section of a crystal through which the light is made to pass.

If, while the string is vibrating, the second piece of cardboard, D, is made to revolve through 90°, so that the slit in this card is at right angles with that in the first card, the vibrations of the string will be limited in all directions, and it will cease to vibrate.

If, instead of the string we use a ray of light, and in place of the cardboards we use sections of a polarizing crystal, the vibrations of the ray will be limited to one direction, but continue to pass, as long as both crystals are in the same relative position. If we conceive a cross section of a ray of light magnified, we might represent the path of the vibrations of the molecule by the spokes of a wheel as at A. Fig. 16.

Fig. 16.



We may conceive that the molecules of the crystal are arranged in lines so that they interfere with all vibrations not in the same plane as these rows of molecules.

In the first crystal we may conceive these rows to be vertical. The light, after passing through this crystal, as shown in cross-section at B, is seen to be polarized in the vertical plane, *i. e.*, the vibrations of the particles of ether are reduced to one plane.

If a second crystal be interposed in the path of the polarized ray, and held in the same position with reference to its axes or lines of molecules, the ray will pass unobstructed.

If the second of the crystals be rotated through 90°, this will interfere with the vibrations of the ray as polarized by the first crystal, and they will cease; *i. e.*, no light will pass through this second crystal. Only those vibrations can pass this crystal which take place in the plane shown in C, at right angles with those shown by B. Polarizing crystals cannot be supposed to contain slits, as here indicated, but their molecules are so arranged as to sift the light that passes through them and limit the vibrations of the luminiferous ether, just as the slit in the cardboard, in our first illustration, does the vibrations in the string.

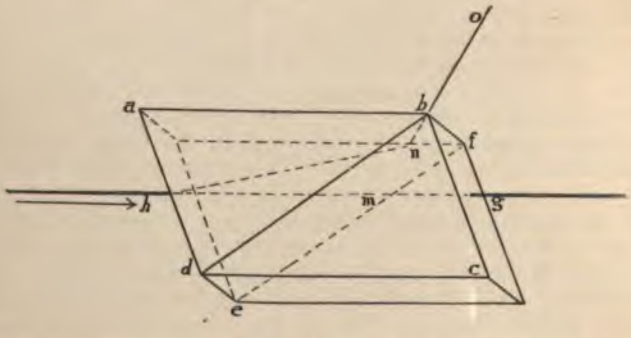
If, in the above experiment, we place the cards upon the string, so that the slit in one makes an acute angle with that in the other, the string will still continue to vibrate, but it will swing through a shorter distance, which will grow shorter as the second card is rotated. That is, the vibrations are gradually stopped as the card is turned. The same phenomena are observed with the crystals. If the crystals are placed in the same position with relation to their principal axes, the light passes freely. If one of them be rotated, the transmitted light grows gradually less and less until the crystal is turned through 90°, when almost total darkness results. There is nothing in the appearance of a polarized ray to indicate to the naked eye its peculiar condition; but if the eye be aided by a polarizing prism, it is easy to detect the fact that it is polarized.

Double Refraction and Polarization.—If a black dot on a sheet of paper be looked at through a crystal of Iceland spar (Calcite), there appear to be two dots. The ray of light in passing through the crystal to the eye is split into two rays of equal brilliancy. If the crystal be rotated, one of the dots revolves around the other. The ray that gives the stationary image is called the **ordinary ray,** while the other is called the **extraordinary ray.** Both rays are polarized, and in planes which are at right angles to each other. It is found that certain non-crystalline substances, like muscle, cilia, etc., are doubly refracting.

The Nicol Prism is the prism usually employed as the **analyzer** in polariscopes. It consists of a rhombohedron of Iceland spar divided through its obtuse angles b, d, e, f, Fig. 17, and at right angle with the surface a, b, c, d. The cut surfaces are polished and cemented together again in the former position, with Canada balsam.

When a ray of light is passed into such a prism, it is split into two portions, *hm*, the extraordinary, and *hn*, the ordinary ray. When *hn* meets the Canada balsam at *n*, it undergoes total refraction and passes out in the direction *no;* while the extraordinary ray passes through and emerges alone in a direction parallel to the entering ray. By the use of such a prism the light is completely polarized in one plane.

FIG. 17.



If a second Nicol prism be mounted in a tube so that the light may pass directly through both prisms, we have, in principle, an instrument known as the polariscope. When the two prisms, thus mounted, are in the same position with reference to their axes, the light passes readily through both. On rotating one of the prisms to the right or to the left, the light is more and more obstructed until the prism is turned through 90°, when very little if any light passes through. The use made of this property of the Nicol prism will be referred to again.

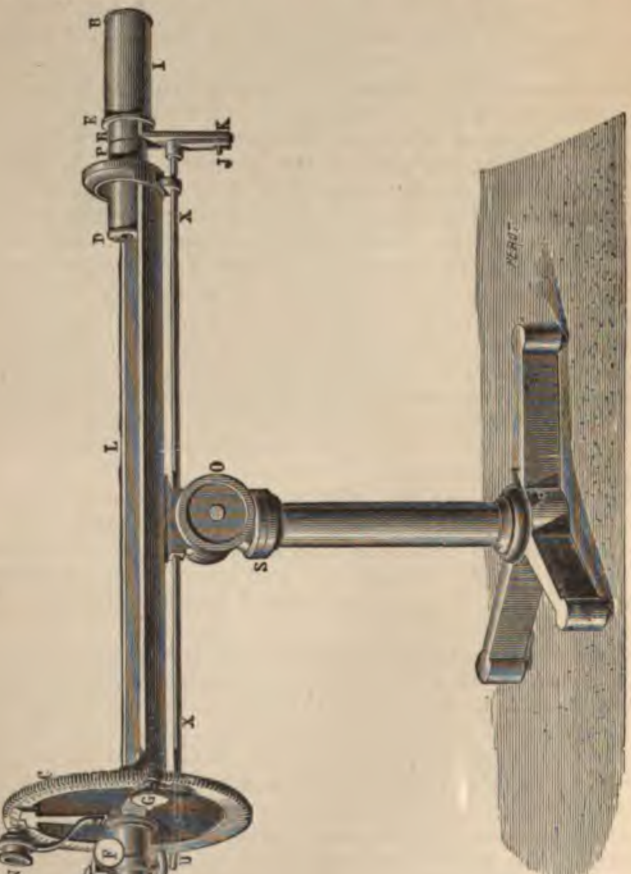
Rotation of the Plane of Polarization.—Certain crystals, such as quartz, certain fluids, such as turpentine and solutions of certain substances like sugar and albumin, have the power of rotating the plane of the polarized ray sent through them to the right or left. Such substances are said to be **optically active.** The degrees of a circle through which the rotation occurs, often serve for the accurate estimation of these bodies. This method may be used for the estimation of the sugars, turpentine, certain alkaloids, albumin, etc. The rotation produced is different for different kinds of light. White light is split into its various colors, each color being rotated differently. White light cannot, therefore, be employed for transmission through the instrument in these examinations. A monochromatic light, usually that from volatilizing a sodium salt in the flame of a Bunsen burner, is employed. This gives a bright yellow light, which is practically monochromatic.

Polarimeters or Polariscopes are instruments for determining the strength of solutions of sugar, albumin, etc., by the direction and amount of rotation they produce in the plane of polarized light. They are sometimes called **saccharimeters,** because they are constructed especially for the estimation of sugar.

There are in the market various forms of polarimeters, but in all forms of the apparatus the polarizer, or means of obtaining a beam of polarized light, consists of the Nicol prism above described. The analyzer is composed of a similar Nicol prism, and a telescope is frequently employed as an eye piece. The polarizer is mounted at P.R. (Fig. 18). The analyzer is so mounted at H that it may be rotated about its long axis, and is provided with an arm which moves upon a graduated scale, so that the degree of rotation from the zero point may be measured in degrees of the circle. A solution of the substance to be examined is placed in a tube with glass ends and brought between the polarizer and analyzer in the support L. The light after being polarized passes through the tube and then through the analyzer.

Laurent's polarimeter (Fig. 18) is one of the simplest and best. In this instrument one-half of the field of vision is covered by a very thin plate of quartz, which slightly rotates the plane of the light passing through it, and causes some light to pass even when the polarizer and analyzer, both of which are Nicol prisms, are crossed. If the analyzer (H) be rotated so as to cause the

FIG. 18.



THE LAURENT SHADOW POLARIZING SACCHARIMETER.

quartz plate to become dark, the light passes through the uncovered half of the field. In an intermediate position the two halves of the field appear equally illuminated. The scale (C) is so graduated that this position of the analyzer is made the zero point of the instrument. The slightest deviation of the analyzer from this position causes one-half of the field to appear darker and the other half lighter. There is thus presented to the eye two lights to be compared, and the instrument is thus very sensitive. Monochromatic light must be used. In some instruments the circle is divided both into degrees and sugar units, or percentages. The scale is read by means of a vernier and lens (N). Before using an instrument, the observation tube is filled with water and placed in position between the analyzer and polarizer. If the instrument is properly adjusted, the zero mark on the vernier will correspond with the zero point of the scale, when the two halves of the field are equally illuminated. The tube is then filled with the solution to be tested and again placed between the analyzer and polarizer, when, if it is an active substance, the plane of the polarized ray coming from the analyzer will be turned to the right, or to the left, in passing through the solution, and one-half of the field will be lighter than the other. The amount of rotation of the plane of the polarized ray will be proportional to the amount of the active substance in the solution. It will now be necessary to rotate the analyzer (H) to the right or to the left, so that the two halves of the field will again appear equally illuminated. When this has been accomplished, we may read off on the vernier the degrees of the circle through which the analyzer has been rotated. In this way the amount of rotation of the polarized ray is determined.

The specific rotary power of any substance is the amount of rotation of the plane of polarized light, in degrees of a circle, produced by 1 grm. of the substance dissolved in 1 c. c. of the liquid, examined in a tube 1 decimeter in length. The specific rotary power of a substance is obtained by dividing the angular rotation observed in the polarimeter (a), by the length of the tube in decimeters (l) and by the number of grms. in 1 c. c. of the liquid (w). If a sodium flame be used as a source of light, the specific rotation of the substance is that of light with wave lengths corresponding to the D line of the solar spectrum, and is usually denoted by $(a)_D$. Then the above statement may be expressed as follows:—

$$(a)_D = \pm \frac{a}{w\,l.}$$

In this formula plus indicates that the substance is dextrorotatory and minus that the substance is levorotatory. If in this formula the specific rotatory power of the substance under examination be known and we wish to find the value of (w), or the weight of the substance, then the formula becomes:

$$(w) = \pm \frac{a}{(a)_D \times l}$$

In this formula, a is the observed rotation, l the length of the tube in decimeters, which is known, and $(a)_D$ the specific rotatory power, which has been determined for all well-known optically active substances. w can easily, therefore, be calculated. The specific rotatory power of a few of the most important optically-active substances are as follows:—

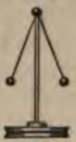
Cane sugar, $(a)_D = + 73.8°$
Milk sugar, " " $+ 59.3°$
Dextrin, " " $+ 130.8°$
Dextrose, " " $+ 56°$

Levulose, $(a)_D = - 106°$
Egg albumin, " " $- 33.5°$
Serum " " " $- 56°$
Gelatin, " " $- 130°$

ELECTRICITY.

Electricity Produced by Friction.—If a piece of glass rod or tube, sealing-wax, resin, or sulphur be rubbed briskly with a piece of flannel or silk, it will be found to have acquired properties which it did not previously possess, namely, of attracting to itself such light objects as bits of paper, feather or dust. After adhering to the glass rod for a few seconds these objects are thrown off again with a perceptible force. This property was first observed in amber, or **electron**, as the Greeks called it, as early as 600 B. C. Dr. Gilbert, of England, about 1600, showed that a very large number of bodies exhibit the same property, which he called **electrics.** Since his time the name **electricity** has been used to designate the agency at work to produce these phenomena. A better way of showing these phenomena is by means of a ball of elder-pith suspended by a fine silken thread. If the excited glass rod be presented to the pith-ball, the latter is attracted and then thrown off. If, now, a piece of sealing-wax be rubbed and presented to the electrified pith-ball, the latter is strongly attracted to it. In other words, a pith-ball that has been charged by the glass is repelled by the electrified glass, but is attracted by the electrified sealing-wax; or, if electrified by sealing-wax, it is repelled by it and attracted by the glass. We thus have two kinds of electricity developed by these two substances. If two pith-balls be suspended by silk threads so as to touch each other, and they are both electrified or charged by the same piece of glass or sealing-wax, they will be thrown apart and held in this position as long as they remain charged. (See Fig. 19.) If one ball be charged from glass rubbed with silk, and the other be charged with sealing-wax rubbed with flannel, they will then attract each other.

FIG. 19.



This fact is usually stated in the following law:— **Bodies similarly electrified repel, and bodies oppositely electrified attract one another.**

This law will be referred to again as an aid in the explanation of many other phenomena.

The kind of electricity produced in the above experiments depends not only on the thing rubbed, but also on the rubber; for glass yields the one kind when rubbed with silk, and the opposite kind when rubbed with cat's skin. Resin and sealing-wax rubbed with an amalgam of tin spread on leather, yields the same electricity as glass when rubbed with silk, but yields the opposite kind when rubbed with flannel. That kind produced by glass and silk has received the name of positive (+) electricity; the electricity produced by resins rubbed with wool has received the name of negative (—). These two—positive and negative electricities—when brought together in a body neutralize each other, and the body then shows no electricity at all. The electrification of either kind produced by friction or other means upon the surface of a body is called a **charge.**

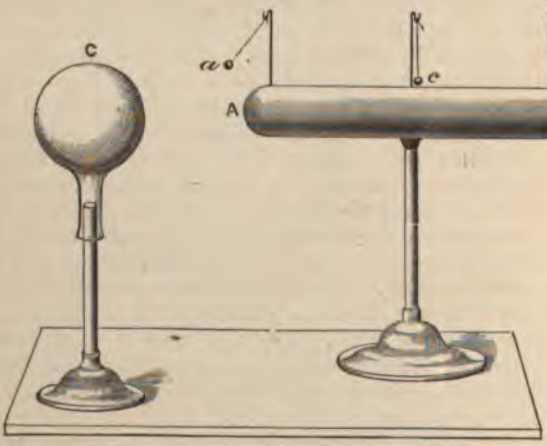
The body which shows the electrical phenomena is said to be **charged.** A charge may be large or small, positive or negative. When the body is brought again to the natural condition, it is said to be **discharged.** Good conductors of electricity are discharged by bringing them in contact with the ground, or touching them with the hand. The discharge is usually instantaneous, and is accompanied by a snapping sound and a flash of light, called a spark, which, when received on the hand, produces a pricking sensation.

The condition of electrification is generally conceived to be a peculiar disturbance brought about in the molecules of a body or of the **ether** surrounding them. This condition or disturbance is capable of being imparted to neighboring molecules of certain kinds, but not readily to all molecules. Bodies whose molecules are readily affected by the electrical disturbance, and transmit it from one to another, are said to conduct electricity, or are **conductors**; those whose molecules do not readily take up and transmit this disturbance are called **insulators.** If, for illustration, the balls in the apparatus represented in Fig. 10, p. 32, are made of some elastic substance, the force of the ball A is transmitted to B; but if the balls are made of loosely-wound yarn the force is not transmitted. Whether the force is transmitted will depend upon the composition of the balls. So in electricity, the question of conductivity depends upon the composition of the molecules.

The metals are generally good conductors of electricity, while gases and the non-metals are poorer conductors. Electricity may either reside upon the surface of bodies as a **charge,** or it may be transmitted through their molecules as a current.

Electricity by Induction.—If we electrify by friction a glass globe or flask, mounted upon a glass support, and then bring near it, as represented in Fig. 20, a large sausage-shaped metallic conductor, also mounted upon a non-conducting glass support, we shall find that the two ends of this conductor exhibit all the properties of an electrified body. They will attract bits of paper; and pith-balls mounted upon these ends are repelled, as shown in the cut, while the centre of the conductor shows no

FIG. 20.



sign of electrification. Further examination will show that the two ends show opposite kinds of electrification. The end nearest the electrified glass will show a negative charge, while the other shows a positive charge. When the glass globe is removed, the two charges neutralize again and disappear. This influence of an electrified body upon another body near it is known as induction.

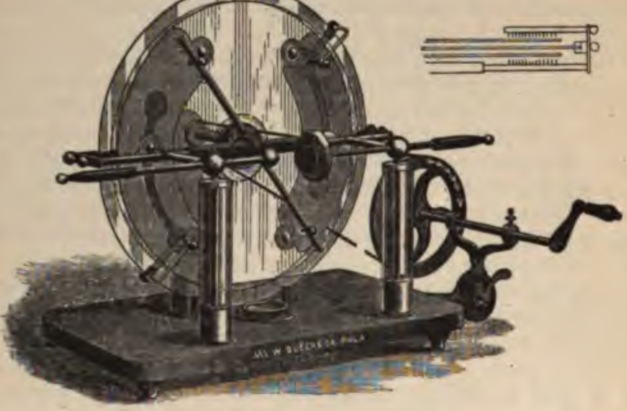
It appears, then, that a positive charge attracts negative and repels positive, and that this influence is exerted at a considerable distance, separating the two charges in the body acted upon as long as the inducing body continues near it. The quantity of the two charges thus separated will depend upon the quantity of the charge upon the inducing body, and its nearness to the conductor. By the quantity of a charge of electricity we mean its power of doing electrical work in returning to a state of equilibrium. This is more generally spoken of as its **potential**.

For example, a highly-charged body, when touched with the finger, will give a long, brilliant spark, or will strongly attract light bodies, while one charged with a low potential may give no perceptible spark, and attract only very small bodies. It is common to hear a positive charge referred to as a high potential, while the negative is referred to as a low potential.

Other Sources of Electricity.—Friction is not the only means of generating electrical disturbances. Other agencies are percussion, compression, heat, chemical action, crystallization, physiological action, contact of metals, vaporization, magnetism, etc. Indeed, it is now known that very many natural processes are accompanied by electrical disturbances. Of the many possible ways of producing electricity, the principal ones employed to advantage are friction, chemical action and magnetism. The first of these combined with induction, is utilized in the so-called static machines; the second in the ordinary galvanic battery, and the third in the dynamo-electric machines, used for developing powerful currents. For medical purposes the first two kinds of machines are chiefly used at the present time.

Static Electric Machines.—For the purpose of generating large quantities of electricity, various kinds of electrical machines have been devised. In the earlier machines a glass cylinder was used, mounted on a horizontal axis, and provided with a crank with which to revolve it. Upon this cylinder a rubber, made of leather dusted with tin or zinc amalgam, was pressed. The rubber was connected with the earth, while a brass comb or row of points connected with a conductor, similar to the one represented in Fig. 20, allowed the positive electricity to escape from the glass cylinder to the conductor, and the negative to escape from the conductor to the glass cylinder. Glass discs were then substituted for the cylinder. In the more recent machines, known as the Toepler-Holtz machines (see Fig. 21), the rubbers are dispensed with. The charge is developed entirely by induction produced by rapidly revolving a glass plate or disc near a stationary disc bearing two armatures, one of which must contain a small initial charge to begin with. For a detailed description of this somewhat complicated machine the student is referred to works on Physics. It is so arranged that either a constant current may be obtained, giving most of the effects of the galvanic current, or intermittent shocks giving the effects of the interrupted currents, or those of the electric bath. As the potential of static electricity is much greater than that of galvanic, about to be considered, it may be applied through the clothes, and thus obviates the necessity of uncovering the part to be brought under its influence; a fact greatly appreciated by many patients.

FIG. 21.

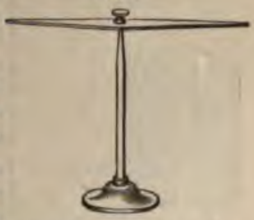


MAGNETISM.

Properties of Magnets.—The name magnet, or lodestone, was given by the ancients to certain black, hard stones found in various parts of the world, which possessed the power of attracting to themselves bits of steel or iron. About the tenth or twelfth century these magnets were discovered to point north and south when suspended by a thread. Natural magnets are an ore of iron, known as magnetite, having the composition Fe_3O_4.

If a piece of hardened steel be rubbed with one of these natural magnets, it acquires the properties of the magnet and retains those properties for a very long time. If a piece of soft iron be treated in the same way, it becomes a magnet when in contact with the magnet, but loses its magnetic properties when the latter is removed. The peculiar qualities of a magnet are easily shown to be manifested chiefly at the two extremities only, when brought near an electrified body, as was noted in the case of the conductor A B, in Fig. 15. If a bar magnet be dipped into a keg of small nails and withdrawn, a large number of them will adhere to the two ends of the bar. The two ends where the magnetic force is strongest are called its poles. A light magnet balanced at the centre upon a needle point, so as to allow freedom of movement, is called a magnetic needle. (See Fig. 22.) Such a needle always arranges itself nearly due north and south, and always in the same position. The compass sold by opticians is simply such a needle mounted above a dial, marked with the "points of the compass." The end of the needle or magnet that points to the north is called the **north pole,** and the other the **south pole.** If a magnet be broken at any point between the two poles, each of the pieces becomes a magnet with two poles; it is therefore impossible to make a magnet with but one pole. In magnetism, as in electricity, like poles repel and unlike poles attract each other. The force with which a magnet attracts or repels another magnet, or a piece of iron, is called the magnetic force. The magnetic force acts through all kinds of bodies except iron or other magnetic metal, and varies inversely as the square of the distance. Iron, nickel, cobalt, cerium, chromium, and manganese are recognized as magnetic metals. Paper, porcelain, and oxygen gas are feebly magnetic. Magnetism may be induced in a piece of iron by the near presence of a magnetic pole. If iron filings be sprinkled over one end of an ordinary iron bar, and one of the poles of a permanent magnet be brought near the other end of it, the filings will be attracted by the iron bar.

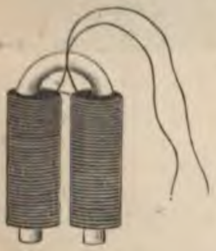
FIG. 22.



The pole of the bar nearest the magnet will be found on examination to be of the opposite kind to that of the magnet; in this respect magnetic induction resembles electric induction. The magnet is not weakened by the induction, but rather strengthened by the reaction of the newly-made magnet upon its polarity. Artificial magnets may be made into any desired form, but the usual forms are the straight bar and the horseshoe form. The latter form admits of the application of a connecting bar of soft iron from one pole to the other, known as an **armature.** When a magnet is not in use the armature should always be applied, to retain the full power of the magnet. Long thin steel magnets are stronger in proportion to their weight than thicker ones; consequently, strong magnets are frequently made of a number of long thin magnets bound together after being magnetized.

Electro-Magnets.—Heretofore we have spoken of but one method of making a magnet, that of contact with another magnet. If a bar of iron be thrust into the hollow of a spiral or coil of insulated wire through which a current of electricity from a battery is made to pass, it becomes a magnet as long as the current passes through the coil. When the current is stopped the iron ceases to be magnetic. Such a bar of iron, surrounded with a coil of wire for the purpose of magnetizing it, is called an **electro-magnet** (Fig. 23). Electro-magnets may be made much stronger than those produced by any other means. If a bar of hardened steel be thus magnetized, it remains a permanent magnet. The strength of an electro-magnet is proportional to the strength of the current passing through the coil, and to the number of turns of wire in the coil. It takes time to produce a magnet by this means, some large magnets requiring from one to two seconds to reach their maximum strength.

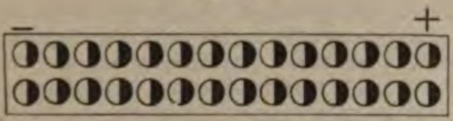
FIG. 23.



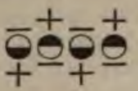
The magnets of large dynamo-machines frequently take as long as ten minutes to rise to their full working strength. If, into a coil of insulated wire connected with a means of showing minute currents of electricity, a steel bar magnet be thrust, there is a momentary current sent through the wire by the inducing action of the magnet. On now suddenly withdrawing the magnet, a current is produced in the opposite direction in the wire. These facts will be referred to again when we come to speak of the action of the induction coil.

Theory of Magnetism.—The best explanation of the phenomena of magnetism is afforded by supposing that each molecule of the bar is a separate magnet; for, if the magnetized bar be broken in small pieces, each piece is found to be a perfect magnet. If this process of mechanical division be continued far enough, we will ultimately arrive at the molecule. Each molecule will then have two poles, one seeking the north and the other seeking the south end of the bar; or, when a bar of iron or steel is magnetized, the molecules are all so arranged that the same poles point in one direction, as represented in Fig. 24.

FIG. 24.



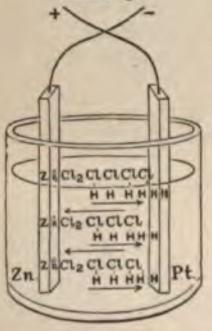
By this theory we conclude that when a piece of iron or steel is neutral, the molecules arrange themselves so that they satisfy each other's polarity, forming closed magnetic circuits among themselves, thus:—



In molecules of chemical compounds, the one kind of atoms is inherently electro-positive, or north-seeking, and the other electro-negative, or south-seeking; and chemical affinity is the manifestation of this polar energy acting between two kinds of differently polarized atoms or groups of atoms.

Electricity Produced by Chemical Action.—If, in a vessel of water containing a little sulphuric or hydrochloric acid (1 to 20), a strip of zinc and one of copper or platinum be immersed and prevented from coming in contact, no action is seen to take place, provided the acid and zinc be pure. If, however, we connect the two strips of metal by a wire, or the upper ends of the strips are brought in contact, chemical action immediately takes place, and the following phenomena are observed: 1st. Small bubbles of gas are seen to collect on the surface of the platinum strip, while the zinc slowly dissolves, and at the same time the acid begins to disappear. In the case of hydrochloric acid, the chlorine combines with the zinc, and the hydrogen escapes from the opposite plate. 2d. We shall find a peculiar property manifested by the wire. If a magnetic needle be placed near the wire it is turned from its course. If the wire be broken and the tongue be placed between the two ends, a tingling, metallic taste is observed. If the plates are large, and the ends of the wires are placed near together in a solution of copper sulphate, the metallic copper begins to deposit on one of the wires. In a word, a force is developed in the wires which we call **electricity.** If the wires are separated from each other by air, the chemical action ceases, the gas ceases to escape, and the zinc to dissolve. The same phenomena are observed when we substitute for the above metals, zinc and lead, zinc and gas retort carbon, etc. It is only necessary that the plates be unequally acted upon by the fluid in which they are dipped; and the greater this difference, within certain limits, the stronger is the force developed in the wire. In order that these phenomena shall take place, the following conditions are necessary:—

Fig. 25.



The plates and connecting wires must be conductors of electricity.

The liquid must contain some substance with which one of the plates can form a chemical action.

Theory of the Galvanic Cell.—In order to bring the working of the cell clearly before the mind, let us assume the plates in Fig. 25 to be platinum and zinc, and the exciting fluid to be a solution of hydrochloric acid. The space between the plates may be considered to be filled with molecules of the acid, each molecule composed of one atom of negative chlorine united to one atom of positive hydrogen. The negative chlorine atoms have an inherent tendency to combine with the positive zinc atoms, which are capable of taking a higher positive condition than hydrogen, and by this tendency the zinc atoms become strongly charged with positive electricity or positive polarity, which they retain as long as they are in combination with the chlorine. By this means the rest of the zinc plate becomes negatively polarized or loses electricity.

Now, it is clear that if there is no chance for the plate to communicate with the earth, or some neutralizing body, it will soon reach the maximum degree of negative polarity that can be induced by the chlorine. The action must then cease until the equilibrium of the polarity or electricity in the plate has been established; or in our primitive cell, until the wires connecting the plates are brought in contact, when a neutralization takes place, and the action continues.

Thus far we have considered only the negative plate. When the chlorine atoms leave the hydrogen for the more positive zinc atoms, the hydrogen seizes upon the neighboring chlorine atoms in the adjoining molecules, and thus a stream of hydrogen atoms sets toward the platinum plate and are finally liberated at its surface. At this point two atoms combine to form a molecule of hydrogen; but in order to do so, one of the atoms must discharge a part of its positive charge of electricity upon the platinum plate, thus charging it with positive electricity.

By the above process, the zinc plate is rendered negative, or its electric tension is lowered below the normal by the withdrawal of positive electricity, while the platinum plate is actually charged above the normal, and is in a positive electrical condition. It is this difference of electrical state which causes a neutralization through the wires as long as the exciting fluid and the zinc plate last, or as long as the chemical action continues. If the wires are disconnected, the platinum plate soon becomes charged to a tension equal to that of the hydrogen atoms, and the zinc plate lowers its tension until the chlorine atoms will no longer leave the hydrogen to combine with it. The action then ceases until the connection is again made. The discharge is then continuous from the platinum to the zinc plate, and it can also be shown that a current passes through the liquid. Such is the best conception we possess of the simple galvanic cell which we have considered.

The Current or Circuit.—The circuit is said to be **closed** when the wires are connected, and there is a constant flow or transfer of force through the wires and through the liquid. It is said to be **open** or **broken** when the wires are separated so that the transfer of force ceases.

If the wires from a galvanic cell, or a collection of cells, be connected with the earth instead of with each other, the current flows as if the latter were really done; and it makes no difference how far apart the wires connect with the earth. This is called **grounding** the battery. No current actually flows from one point to the other in the ground, but by bringing the plates in contact with the earth their electrical equilibrium is restored.

This principle is made use of in telegraphy to avoid the necessity of a return wire. One of the wires of a battery situated at one of the stations is **grounded,** while the other passes to and through the other station and is then grounded at that point; the current must pass between and through both stations to complete the circuit, or restore the equilibrium.

Electrical Tension or Electro-motive Force.—When we speak of the normal electrical condition, we have reference to the electrical state of the earth or bodies in contact with it. The earth is the great storehouse of electricity, as the ocean is of water. If water be taken up from the ocean, and deposited upon the mountain side, it will run back to the sea in a stream, and can be made to do work, while reaching its former level, by turning a water-wheel. The water, in other words, has acquired power to do work, by its change of position, which in mechanics is called **potential.** In the galvanic cell, the equilibrium of electricity is disturbed, and it acquires power to do work in returning to its former state of electrical equilibrium. This property in electricity is called **tension, potential,** or **electro-motive force** (E. M. F.). The strength of the E. M. F. will, of course, depend upon the difference in the electrical condition of the two plates. It is our purpose to consider here only such practical points as we deem essential to the physician's knowledge in the use of galvanic batteries.

Electrical Units.—There are in common use among electricians certain units of measure applied to currents, which it is convenient for the student to understand. The unit of **electro-motive force** is called a **volt.** It is the power of the current to overcome resistance, and it is very nearly that of the Daniel or Callaud gravity cell. The E. M. F. or the **voltage** of these cells is about 1.079 volts per cell.

The unit of resistance which a current encounters in its passage, and which must be overcome before an electrical circuit can be completed, is called the **ohm.**

Just as there must be sufficient pressure of water to overcome the obstacles offered by friction and short curves in the pipes, before water will be delivered, so must there be sufficient voltage to overcome the high resistance offered by poor conductors, like the human body, before there will be a passage of current. The actual current, then, that produces effects, or does work, is produced by the excess of electric force over that which is required to overcome the resistance in the conductor. In practice, it is found necessary to employ from 30 to 40 cells of battery, according to the type, in order to secure electro-motive force sufficient to overcome the resistance of the body, and have a working excess of current.

The unit of measurement of the passing current is called the **ampère**. An ampère is the strength of current furnished by an electro-motive force of one volt, passing for any given time, through a circuit whose total resistance is one ohm. It is the amount of work the current is able to do in a measured time.

But inasmuch as the tissues of the body could not endure a current of one ampère, the ampère is divided, for medical purposes, into one thousand parts, each of which is designated a **milli-ampère.** The unit of strength of current, then, in medical batteries, is the milli-ampère and represents not the actual quantity or dose, but is analogous to the strength of a solution which we might use externally and refer to as a 5 per cent. solution. As we speak of a pumping engine delivering a 1-inch or a 2-inch stream from a nozzle, the pressure remaining the same, so we speak of the current passing through a conductor as a one-milli-ampère or two-milli-ampère current.

Whenever it becomes necessary to measure the exact quantity or dose administered, we make use of another electrical unit called the **coulomb**, by which we mean the **unit** of **quantity.** The coulomb is such a quantity of electricity as would flow in one **second** through a circuit whose resistance is **one ohm,** under an electro-motive force of **one volt**, or, it is one **ampère-second.** The number of coulombs of quantity is determined by means of an instrument called the coulomb-meter, in which the current is made to decompose water into oxygen and hydrogen; the amount of this decomposition being proportional to the amount of current used. There is still another unit by means of which the total electrical energy is measured, and which is designated the **Watt.** This represents the energy of a current flowing under a difference of potential of one volt, and a strength of one ampère, and is sometimes called the **electrical horse power**. It is expressible in mechanical units; 746 Watts being equal to one horse power, or one Watt $= \frac{1}{746}$ horse power. To estimate the electrical energy of any current, the E. M. F. in volts is multiplied by the number of ampères of current strength.

$$\frac{\text{Volts} \times \text{Amperes}}{746} = \text{horse power.}$$

Legal Units.—The following units were adopted or confirmed by the International Electrical Congress at Chicago in 1893, and legalized by the United States Congress in 1894.

The **international ohm** is to be the resistance offered by a column of mercury, at 0° C., weighing 14.4521 grms. and having a length of 106.3 centimeters, and having a uniform cross section throughout the length of the column.

The **international ampère** is to be such a current as will deposit from a neutral solution of silver nitrate, 0.001118 grms. of silver per second, or 4.025 grms. per hour. The ampèrage of a current may be determined by depositing silver, and weighing the amount deposited in a given time.

The **international volt** is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampère. It is represented by $\frac{1000}{1434}$ of the electro-motive force of a standard Clark's cell, at a temperature of 15° C.

The **international coulomb** is a quantity of electricity transferred by a current of one international ampère in one second.

The **international farad** is the unit of capacity. It is the capacity of a condenser charged to a potential of one volt by one coulomb of electricity.

The unit of work is the **joule,** which is equal to ten million units of work in the centimeter-gramme-second system, and which is practically equivalent to the energy expended in one second by an international ampère in an international ohm.

The unit of power is the **watt,** which is equal to ten million units of power in the centimeter-gramme-second system, and which is practically equivalent to the work done at the rate of one joule per second.

The unit of induction is the **henry,** which is the induction in a circuit when the electro-motive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampère per second.

The Milliampère-meter.—This is an apparatus introduced into the circuit, in order that the current strength the patient is receiving at any given time may be accurately measured. Its action depends upon the fact discovered by Oersted, in 1841, that, if a magnetic needle be mounted near a wire, in which a current is passing, it will be deflected. He found that if a current be sent along a conductor brought near to and parallel with a needle (see Fig. 27), it would cause a deflection of the needle in the direction shown by the curved arrows. He found further, that the amount of this deflection will depend upon the strength of the current in the wire, and upon the proximity of this to the needle. If the conductor be returned upon the under side of the needle, so that the current shall flow in the opposite direction, the needle will be still more deflected, and in the same direction. By using a number of turns of insulated wire, *i. e.*, forming a coil, as shown in Fig. 26, a multiplication of the deflecting power will be obtained. The plane of the coil must coincide with the plane of the earth's magnetic meridian. If this needle be suspended or mounted over a dial having a scale of degrees marked upon it, the number of degrees through which the needle swings under the influence of a certain current passing through the coil, will indicate the strength of the current. In other words, such an instrument would be a **galvanometer** or **electro-meter.**

If the scale is so divided as to read the current strength in ampères or milliampères, the instrument would be known as an **ampère-meter** or **milli-ampère-meter.**

FIG. 26.

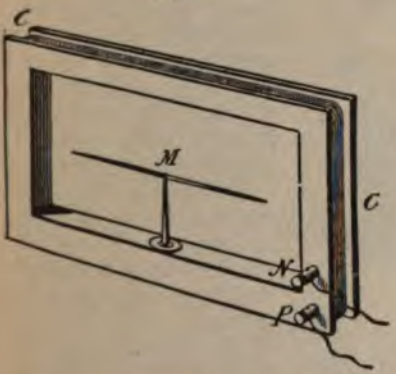
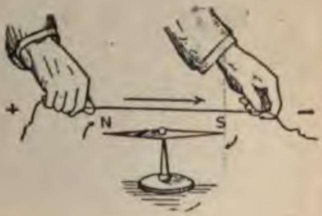


FIG. 27.



In the above described milli-ampère-meter, the instrument must be first adjusted with the magnet exactly in the magnetic meridian. The instrument must be carefully leveled before the reading is taken. The needle will then point to zero on the scale.

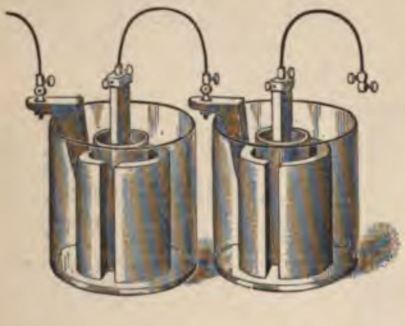
To avoid this adjustment, milli-ampère-meters are now often constructed with the needle mounted in the field of a permanent magnet, which serves to bring the magnet always to zero when no current is passing through the coils, regardless of the position of the instrument. Milli-ampère-meters are sometimes employed, in which the elastic force of a coiled spring is applied to bring the needle quickly to rest, or cause it to "dead-beat" without any delay from oscillations. The strength of current to be applied to the human body varies greatly, according to the effect to be produced, from 10 to 300 milli-ampères.

Forms of Cells.—We have thus far discussed only one form of cell. The term **battery,** strictly speaking, is applied to a collection of cells; but it is frequently applied to a certain form of cell. Various kinds of cells are in common use.

One difficulty in the working of the simple cell we have already described, is that the hydrogen accumulates on the platinum plate and prevents contact with the liquid, and thus obstructs the current. In order to obviate this, various means have been used to prevent this gas from reaching the platinum.

In **Grove's** cell (Fig. 28), the platinum plate is suspended in a porous earthenware cup filled with strong nitric acid, and placed in the center of the larger cup, containing dilute sulphuric acid (1 to 12). The nitric acid oxidizes the hydrogen, converting it into water before it reaches the platinum.

FIG. 28.



Bunsen's cell is constructed in the same way as the above, except that the platinum is replaced with the cheaper gas retort carbon.

In the working of the above cells the nitrous fumes evolved are very objectionable, and to avoid this, a solution of chromic acid in sulphuric acid, made by adding to 18 parts of water 4 parts of potassium bichromate and 4 of sulphuric acid, may be used. The chromic acid serves to destroy the hydrogen in the same way as the nitric acid, and no porous cup is needed. The elements used are zinc and carbon. This cell gives a strong current for a short time, and is one of the best in use, for medical purposes. The zinc plates are always removed from the liquid when the battery is not in use. In some medical batteries a solution of acid sulphate of mercury in water is used as the exciting fluid, instead of the above. In this case the plates are small, and made of zinc and carbon. The zinc combines with the sulphuric acid, and mercury instead of hydrogen is set free. Another form of battery is one in which the exciting fluid is diluted sulphuric acid, and the elements zinc and silver; the latter being inclosed in a layer of chloride of silver, which is intended to prevent the hydrogen from accumulating on the silver plate, by combining it with chlorine. $2AgCl + H_2 = Ag_2 + 2HCl$. These cells are usually made in the form of long narrow cylinders, so as to occupy a small space, and are very constant and effective.

In the **Leclanché** cell (Fig. 29), as usually constructed, the elements are a plate of carbon and a rod of zinc. The carbon plate is surrounded by a layer of peroxide of manganese, or ferric oxide, to serve as a depolarizing agent. The exciting fluid is a strong solution of ammonium chloride in water. This battery is in very common use where an open circuit is to be used, is very constant, requires attention only at long intervals, and is inexpensive. Various modifications of this cell have been proposed, and of these the Law cell has the advantage of being more durable.

FIG. 29.

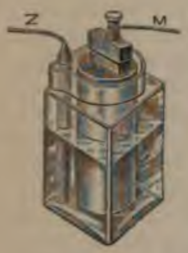
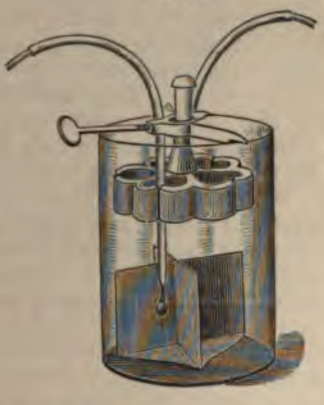


FIG. 30.



The **Callaud** cell (Fig. 30) is constructed as follows. The elements are zinc and copper. The former is suspended in the upper portion of a solution of copper sulphate contained in a glass jar. The copper plate lies at the bottom of the jar, and the wire attached to it is covered with gutta percha for the purpose of insulating it. From time to time copper sulphate crystals are dropped into the jar, to keep up the supply.

This battery is useful where a closed circuit is to be used, and the battery is to be in constant use. It is very constant when kept in good order, but has a low electro-motive force, and is seldom used in the construction of medical batteries.

Care of Batteries.—In order that a battery may perform its work, it will need some care in its management. All metallic connections, as well as the wires through which the current is to pass, must be of good conducting material. Copper or silver wire is usually employed for conductors, and where two wires are meant to connect, their surfaces must be bright and free from oxides, which are poor conductors. As far as possible, a uniform strength of exciting fluid should be maintained. In most batteries this will require entire renewal, from time to time, in order to supply new material for chemical action, and to remove the products of former action.

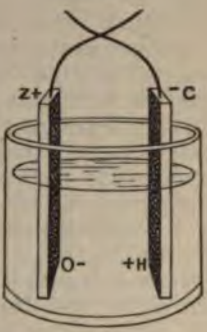
Local Currents.—Owing to the imperfections in the zinc used in the construction of batteries, it is unequally acted upon by the liquid. The points where the zinc is harder, or contains iron, lead, or arsenic, act as negative plates to the rest of the zinc, and thus currents are set up between them which eat away the zinc, and cause a serious loss of material, as well as of force. When the battery is not in use, bubbles of hydrogen gas will be seen to escape from the zinc plate, which slowly dissolves. When in use, this hydrogen prevents contact between the plate and the liquid, thus greatly weakening the action upon the plate and increasing the resistance to the passage of the current from the liquid to the metal. "Amalgamation" of the zinc prevents this action by forming over the surface of the plate a homogeneous layer of zinc amalgam.

To amalgamate the zincs, first wash them in dilute sulphuric acid (1 to 6), and then, while still wet, pour mercury upon them and rub in the drops until the whole surface is uniformly bright and smooth. Or, they may be dipped in a saturated solution of bichloride of mercury (corrosive sublimate) containing a few drops of hydrochloric acid. It is well to keep a little mercury in the bottom of each cell, which keeps the plates amalgamated. A hissing sound, or the evolution of hydrogen from the surface of the zinc, is a sure sign that the zincs need re-amalgamating.

Polarity of the Elements of Batteries.—A serious hindrance to the working of batteries is what is called the

polarization of the plates. We have already referred, when speaking of the construction of cells, to the accumulation of hydrogen on the carbon or platinum plate. When the current is of considerable strength, oxygen accumulates on the zinc plate and hydrogen on the opposite one. We then have a layer or plate of hydrogen against the carbon, and a layer or plate of oxygen against the zinc. The former of these is positive and the latter negative; and they are joined together by the same wires as the primary plates, as will be seen by a glance at Fig. 31. Not only is the liquid kept from perfect contact with the plates, but, owing to the action of the liquid upon these new gaseous plates, a current is developed in the opposite direction to that of the primary current, which may become so strong that it almost entirely overcomes the original current and destroys the efficiency of the battery.

FIG. 31.



Some method must be adopted, therefore, to prevent the hydrogen from accumulating upon the carbon or platinum plate. Nitric or chromic acids, oxides of manganese, copper or iron, silver chloride and copper sulphate are all used for this purpose.

Secondary or Storage Batteries.—The polarity of the plates of a battery cell is utilized in the **secondary or storage batteries.** The cell contains two or more plates of large size, constructed of sheet lead, or one is made of sheet lead to be connected with the negative pole, and the other of peroxide of lead to be charged from the positive pole of the charging battery or current. The E. M. F. of such cells is about 2 volts during discharge. The cell is filled with dilute sulphuric acid. The plates are polarized by passing a current through the battery. The hydrogen accumulates in or upon one plate, and the oxygen in the other. On now disconnecting the charging battery, it is found that a current may be obtained from the polarized cell for some time, but in the direction opposed to that of the charging current. When the plates of this battery are once charged, they will remain charged for some weeks, and the current may be obtained at any time, by connecting the wires from the opposite plates.

Resistance of Conductors.—Conductors are bodies which allow a ready transmission of the electrical impulse through them, and are contrasted with another class of bodies called non-conductors or insulators. These terms, however, are only relative.

Some bodies conduct electricity with great ease, while others offer more resistance to the passage of the current, or entirely refuse to allow an appreciable amount to pass. Even the best conductors offer some resistance to the passage of the current. The metals are the best conductors, and of these silver is the best conductor known. Copper is second only to silver, and when both metals are pure the difference is but slight.

If we compare wires of the same material, but of different sizes and lengths, we find that **the resistance of wires increases with the length, and diminishes as the area of the cross section increases.** When a cell is in action, the current not only meets with resistance in the wires, but also in the liquid of the cell through which it has to pass. This last resistance is usually much greater than that of the wires, and is an important element in determining the strength of the current.

Ohm's Law.—This law states that the strength of a current developed by a battery will be equal to the electro-motive force divided by the resistance. By electro-motive force we mean the force with which the electric current is set in motion, or the difference in potential of the two plates of the cell used. This law may be stated algebraically as follows: $C = \frac{E}{R + r}$, where R represents the internal resistance of the liquid, r the external resistance, or that offered by the wire, and E the electro-motive force, which is always the same when the same metals and exciting liquid are used. In any given form of battery, variations in the strength of the current must be due to variations in resistance, either in the external or internal part of the circuit, or to a change in the strength of the exciting liquid, polarity of the plates, or secondary currents. We have already spoken of the resistance offered to the current by the polarity current, flowing in the opposite direction, and which sometimes becomes almost as great as the electro-motive force can overcome. It is clear that in order to increase the value of C, in the above formula, we must increase E or diminish R and r. To increase the electro-motive force we select such metals and liquids as shall give us a relatively high intensity of current. We may increase the intensity of the E. M. F. by joining several cells, so that the force of the one may be reinforced by the next, and so on.

This is done by connecting the zinc of the first to the carbon of the second, the zinc of the second to the carbon of the third, etc. Each cell added to the series adds to the current its E. M. F. diminished by its internal resistance; the external resistance being too small to be regarded. The formula applied to the series would be, when n equals the number of cells: $C=\frac{nE}{nR+r}$. Now when the external resistance in the wire, r, is very small in comparison with R, as when flowing through an ordinary copper wire, it may be disregarded; and the equation then becomes $C=\frac{E}{R}$. That is, the effect of a battery of several elements, in such a case, is no greater than that of a single cell If, however, the external resistance, r, is great, as when the electrodes are applied to a human body, which has a resistance many times greater than the usual value of R, the value of C increases or diminishes very nearly in the same ratio as the number of cells. For medical purposes, therefore, we usually combine the cells as above described. Elements or cells so arranged, are said to be arranged **in series**, or arranged **for intensity.**

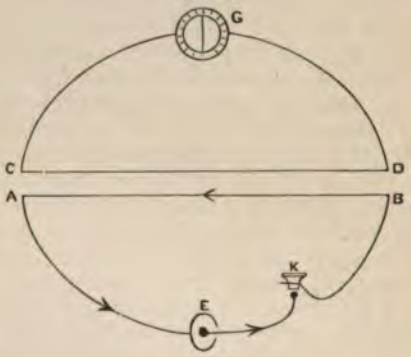
We may also increase the value of C, in the above formula, by increasing the size of the plates, provided the external resistance is small. By so doing we do not increase the electromotive force of the current in the wire, but we reduce the resistance in the cell, by virtually combining several plates into one, and increasing the surface exposed to the liquid, without increasing the distance through which the current has to pass in the liquid. Whether the plates in this case are all in one or different cups, the current only has to traverse the fluid from one plate to another. The internal resistance in this arrangement is small. Where a small resistance is to be overcome, therefore, large plates are to be preferred; or, which is the same thing, all the zinc plates of the battery may be connected, and all the carbon plates. When the cells are arranged in this manner, they are said to be arranged in **multiple arc,** or **for quantity.** The **poles** or **electrodes** of a battery of cells are the conducting wires; that attached to the zinc plate is the **cathode** or **negative** electrode, and that attached to the platinum, carbon, or copper plate is the **anode** or **positive** electrode.

In electro-therapy the term **electrode** is often used to designate the appliance fastened to the end of the wires for application to the patient, while the wires are called **rheophores.**

Induced Currents.—If a current of electricity, from a battery, be passed through one of two parallel wires B A (Fig.

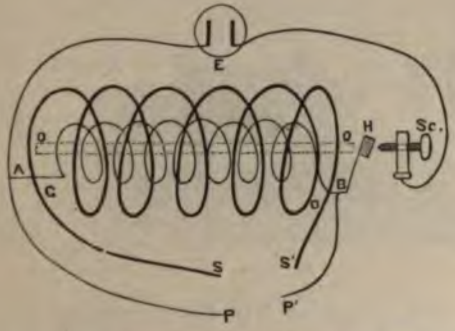
32), lying near together, no current is observed in C D as long as the current in B A is constant; but if this be abruptly stopped, an instantaneous current is developed in C D, which we can demonstrate by connecting this wire with a galvanometer (G). When we make the current pass from B to A, the current in the wire C D takes the direction from C to D; but on breaking the primary current, the induced current takes the direction D to C. If, therefore, we rapidly make and break the primary or battery current by means of the key, K, we shall have a rapid to and fro current, in the secondary wire C D. Now, if these wires be covered with silk or insulated, and are wound together around a spool or bobbin, the conditions of the experiment will remain unchanged, and we shall have the same phenomena in the coiled wires as in the straight. Such a coil is known as an induction or Rhumkorff coil. The strength of the current in the secondary wire, or the induced current, will vary directly as the length of the wire acted upon, the strength of the battery or primary current, and inversely as the distance the wires are from each other.

FIG. 32.



The Induction Coil.—It is customary, in constructing an induction coil, to make the primary coil of large, thick wire, so as to allow the battery current to pass with as little resistance as possible, and to make the secondary coil of a much longer and thinner wire. The former is made into a smaller coil, which slips into the latter, but the two are separate and distinct. Into the inner coil is pushed a bundle of soft iron wires which act as magnets when the battery current is sent through the coil. A small armature or piece of soft iron fastened to a spring, vibrates before the end of the bundle of wires. When no current is passing the spring rests against the point of the screw Sc, Fig. 33. When a current is sent through the inner coil from B to A, an induced current is produced in the outer coil, from S to S′, or from C to D. At the same instant the current B A magnetizes the core of wires O, and the hammer H is drawn toward it and away from the point of the screw. This breaks the current at that point, the core de-magnetizes, the spring brings the hammer back to the screw, and the process is repeated as long as the current from the battery E lasts. The induced current in S S′ is, therefore, a **to and fro** current, or a **make** induced in one direction, and a **break** induced in the opposite direction.

FIG. 33.

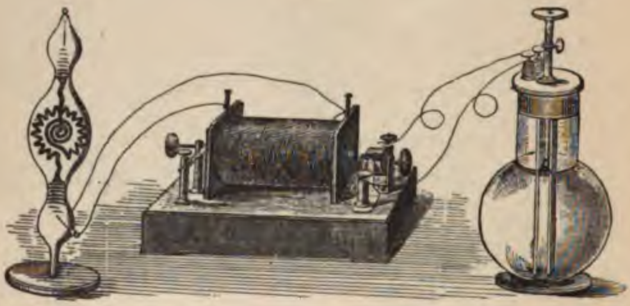


This current is known as the **Secondary, Induced, Interrupted** or **Faradic Current.** The two wires from the battery cell (Fig. 34), are connected with the primary coil, by the binding posts, and carry the battery current. The other wires shown are the terminal wires of the outer or secondary coil, and carry the induced current.

Extra Current.—It is very evident that each turn of wire in the primary coil lies very close to and parallel with the adjoining turns of the same wire, and that these consecutive turns may be considered as constituting a series of parallel wires. In fact, every variation of the current in the wire A B, Fig. 33, generates electro-motive force in the contiguous turns.

An induced current is thus produced in the wire A B, which obeys the same laws as that induced in the independent wire, C D, and in the direction opposed to the battery current, when the latter is made or increased, and in the same direction when it is broken. This current is known as the **primary induced** or **extra current**. During the making or increasing of the battery current, this **extra current,** acting against the battery current, retards or resists it, and hence is not felt at the poles P and P′. At the **break** this current goes in the opposite direction, and, as there is nothing to resist it, may be felt with its full force at P and P′. This current is therefore **interrupted,** and is felt only at the break of the battery current, and always in the direction of this current. The primary induced, or extra current, is feebler than the secondary, because the length of wire acted upon is shorter. As we have just seen, the **make** extra current retards the battery current, so that it takes an appreciable time for this current to attain its maximum force; and the **make** induced current is weakened in proportion to the longer time required. The secondary current developed at the time of making the battery current is therefore weak, and its physiological and chemical effects almost inappreciable. The **break,** secondary, as well as primary, is developed with its full electro-motive force instantaneously; hence, it alone has an appreciable effect when a resistance such as the human body is put into the circuit.

Fig. 34.



Influence of the Core.—As we have stated above, when a galvanic current is sent through a coil of wire wound about a bar of soft iron, the bar becomes a magnet as long as the current passes, and loses its magnetism as soon as the current in the wire is broken. The effect of the bundle of soft iron wires is the same as that of a single bar. Moreover, when a magnet is suddenly made or destroyed, it causes a current to flow through the wire wound about it. The effect of the magnetic core is, then, only to retard the battery current when it is first passed through the coil, and to still further weaken the induced currents developed by it. Its sudden de-magnetization reinforces the break currents and makes them stronger. The currents are further modified by means of a draw tube made to inclose more or less of the primary coil. When this is completely withdrawn the current is strongest; and when the inner coil is completely enclosed by it, the currents are considerably weakened. Occasionally the secondary coil is made to include any desired length of the primary, and thus the current may be varied at will. Fig. 34 shows an induction coil with Grenet cell ready for use.

Magneto-Electricity.—Besides chemical action, other methods of producing electricity may be employed. We have already referred, in the last section, to the effect of suddenly making and destroying a magnet within a coil of wire. The same effect is produced when the magnet is made to approach or recede from the coil of wire, or when the magnet is increased and decreased in strength. The simplest magneto-electric apparatus is composed of a strong horseshoe magnet, before the poles of which two short, soft iron bars, called armatures, mounted on a shaft and wound with coils of wire, are made to revolve by a crank. As the soft iron approaches the poles it becomes a magnet and induces a current in the wire. As it recedes from the poles the current in the wire is reversed, but by a pole changer it is made to pass from the instrument in the same direction.* By multiplying the number of magnets and armatures, by using the current developed to strengthen the magnets, and by revolving the armatures at a high rate of speed, a very large amount of electricity may be produced. The electric light is now very generally supplied with electricity by machines made upon this principle and driven by steam or water-power. Such machines are called dynamo-electric machines. Small machines are sometimes employed for medical purposes, which have been improved by M. Gaiffe so as to give much better results than the older forms of this apparatus. In these machines the electricity is the result of the conversion of mechanical force into electrical force, the two being mutually convertible.

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* In another form of the machine the coil of wire is on the magnet, and the current is produced by the variations in the magnet itself, caused by the varying distance of the armatures.

Thermo-Electric Currents.—If two bars of dissimilar metals be soldered together at one end, thus: $\underset{c}{\overset{a}{\diagdown}\overset{b}{\diagup}}$, and the junction *c* be heated while the ends *a* and *b* are cool and connected by a wire, electricity will pass; the direction of the current will depend upon the metals composing the couple. If the metals be bismuth and silver, the current will be from the former to the latter; if German silver and iron, the current will be from the former to the latter. By arranging a large number of such pairs thus:— –WWWW+, so that alternate junctions can be heated, a current of considerable strength may be produced. Such a series is called a *thermo-electric pile,* and may be constructed by arranging the bars in the form of rays around a hollow centre, in which a lamp or fire can be kept burning, and thus furnish a constant current of electricity. Thermo-electrical currents have not been used in therapy.

Physiological Effects of Electricity.—Electric currents exert a marked physiological effect upon the nerves, the muscles, and the circulation of the human body when it is made a part of the circuit. A constant or galvanic current has a refreshing effect upon a nerve, as well as upon a muscle, through which it is passed. A muscle is able to perform more work under its influence than without it. Under its influence the circulation of the blood in any part of the body may be increased, which increase lasts for some time after the electrodes have been withdrawn. The physiological effect of the negative pole seems to be greater than that of the positive. The interrupted, induced, or Faradic current stimulates nerves most when passed in the direction of the natural nerve current; this seems to be its principal physiological effect. The stimulation seems to be more marked when the interruptions of the current are very rapid and are induced in a long wire of small size. For this reason the recent coils are made with a means of getting extremely rapid interruptions. Drugs may be carried through the skin by the galvanic current. This process is known as *cataphoresis.* The remedy, in solution, is placed between one of the electrodes and the skin, and is carried through the skin into the tissues by the passage of the current.

For more extended remarks upon this part of the subject the student is referred to one or more of the many manuals* upon the subject.

Chemical Effects of Electric Currents.—When a strong galvanic current is passed through a vessel of water containing a little sulphuric acid, the liquid is decomposed, hydrogen gas is given off at the negative pole, and oxygen at the positive. This process is called **electrolysis**. If we perform the same experiment with a solution of a salt of one of the metals, the metal appears at the negative pole, and the negative element or radical appears at the positive pole. If the same current be passed through an animal tissue, the following changes take place: The water in the tissue is decomposed, the hydrogen appears at the negative pole, along with the hydroxides of potassium and sodium, while the oxygen, with the non-metals or acid radicals, appears at the positive. The nascent oxygen and acids surrounding the positive pole attack the neighboring tissues and convert them into a hard eschar, while the alkalies at the other pole exercise their caustic properties and form a soft, frothy mass, containing hydrogen gas in small bubbles.

When a sufficiently strong and somewhat prolonged current is applied to the skin, a similar effect to the above is produced at the point of contact of the electrodes. At the positive electrode the skin first becomes red, with a burning sensation, then an eschar is produced with an acid reaction of the tissues. The eschar resembles that produced by a strong acid. At the negative electrode there is a vesicle formed containing an alkaline liquid; if the action be prolonged, more extensive ulceration takes place. From this it will be seen that strong currents should be used with care, unless it be desired to produce destruction of tissue, as in the removal of tumors, superfluous hairs, etc. When destruction of tissue in a deep-seated organ has been produced by electricity, the eschar is absorbed without suppuration, provided the destruction is not too extensive. By the use of a suitable current regulator, the current used for incandescent lights may be employed for medical purposes, instead of that from a galvanic battery. The effects of the magneto-electric current are very similar to if not identical with those of the galvanic current. Recently the use of frictional electricity in the treatment of disease has been revived and advised as a substitute for Faradic electricity. The effects of this form of electricity have not been so well studied as those of the Faradic and galvanic, but clinical decreases as the temperature increases, although each gas obeys a rule of its own, which can be determined only by experiment. The **volume** of gas absorbed by a liquid at any given temperature is the same, whatever the pressure. The **quantity** of gas dissolved, therefore, increases and decreases with the pressure. When a liquid is exposed to a mixture of gases, it dissolves each in the same proportion as if it alone were present and exerting its own share of the total pressure. Thus when the air, a mixture of oxygen and nitrogen in the proportion of 1 to 4 respectively, is exposed to a mass of water, we find that the gases are absorbed by the water, in the proportion of 1 to 1.87 respectively.

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* De Watteville, Massey, Bartholow, or Beard and Rockwell.

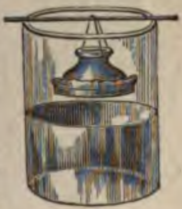
Nature of Solution.—The term **solution** embraces two entirely different processes, the one a mechanical or **physical,** and the other a **chemical** process. In physical solution the identity of the solid is preserved, as well as that of the water; and by evaporation of the water we may obtain it again unchanged. In some cases there seems to be no manifestation of chemical action between the water and the solid. In other cases, which seem at first sight to be equally simple, there is heat developed, or heat absorbed, which, with other things, leads us to suppose that in these cases there is a true but feeble chemical union of the salt with the solvent. When the solid separates again in crystals, it takes a part or all of the water with it as water of crystallization. Simple solution in water may be regarded, in most cases, as a feeble combination of the solid with the water, and then the diffusion of this compound through the remaining water. A **saturated solution** is regarded as a definite compound of the liquid and the substance dissolved. The metallic alloys are in some cases mere mixtures, and in others they seem to be veritable compounds. When a metal dissolves in a dilute acid, there is, at first, a chemical action between the acid and metal, by which a soluble compound is formed. This then dissolves in the water present, as above described. This double process is sometimes termed **chemical solution.**

Diffusion of Liquids.—When one liquid dissolves in another the process is called **liquid diffusion.** If upon the bottom of a vessel containing pure water, we pour some water colored with a little aniline red, by delivering it through a funnel tube so as to prevent the mingling of the two, and then allow the vessel to remain at rest for some hours, the color will be found to have diffused itself throughout the water.

If instead of a colored water we use a strong solution of common salt, having a high specific gravity, we shall find by appropriate tests that the salt has passed throughout the entire liquid. The rate of diffusion in these cases increases, for all substances, with the temperature. This is because the rapidity of motion of the molecules, to which we ascribe the phenomena of heat, increases with the temperature.

Dialysis.—If, in the experiment of the last section, we should interpose a porous partition of earthenware or parchment between the salt solution and the pure water, the result would be the same; the salt would pass through the partition into the water. If, however, we use on one side of the partition a colloidal substance like gelatin or albumin, we shall find that almost none of this body passes through it into the water. Crystallizable bodies pass through the membranes with ease, while those which do not crystallize—called colloids—pass with great difficulty. This property of bodies is made use of to separate the one class from the other. The process of the passage of liquids through porous membranes is called **osmosis.** The **dialyzer** is an apparatus consisting of a shallow vessel provided with a bottom of parchment, or some porous membrane, into which the solution to be dialysed is placed, and the vessel is then floated upon pure water in a larger vessel. (See Fig. 35.) The volume of water should be 8 or 10 times that of the solution to be dialyzed. In the course of two or three days the crystallizable bodies in the solution will be found in the water of the outer vessel, and the colloid bodies will be in the dialyzer.

FIG. 35.



Dialysis is employed to prepare a pure colloid material by dialyzing from it all crystallizable salts. A complex mixture, like the contents of a stomach, is submitted to dialysis for the purpose of separating from it the crystalloids which it may contain, so as to get them in a pure watery solution for analysis.

CRYSTALLOGRAPHY.

Formation of Crystals.—When substances change from the melted to the solid state, or separate from a solution, many of them assume a regular geometrical form, called a crystal. The process is called **crystallization.** The same substance always assumes the same crystalline form when formed in the same way; but under different circumstances, as high and low temperatures, the same substance may have two different crystalline forms, in which case it is said to be **dimorphous.** Different salts of the same metal assume different forms, unless the structure of the molecules is very similar. Thus NaCl, KCl, NaBr, KBr, and KI crystallize alike, in cubes; while K_2SO_4, CNO_3, and KCl assume different forms. The form of the crystal is, therefore, to a certain extent, an index of the molecular structure of the body. There are some substances, like gelatin, albumin, fibrin, etc., which cannot be made to assume the crystalline form. Such bodies are called **colloids,** while those which crystallize readily are called **crystalloids.** In order that crystals may form, it is necessary that the molecules shall be free to move; *i. e.*, cohesion must be overcome to such an extent that it shall not prevent the free movements of the molecules. This condition prevails in solutions, in the melted state, or in the gaseous state. When we evaporate off the solvent, in the case of solutions, we may obtain the crystals with ease. The more slowly the evaporation takes place, the larger and more perfect are the crystals obtained. As a rule, bodies dissolve more readily and in larger quantities in hot than in cold water. A hot saturated solution of any crystallizable salt deposits the excess, on cooling, in the form of crystals. A liquid which is depositing crystals will do so more readily when foreign bodies—as sticks, strings, etc.—are suspended in it. Milk sugar is usually crystallized in this way, upon strips of wood. Advantage is taken of this fact to prepare parlor ornaments in the shape of grass, leaves, etc., covered with alum crystals, which may be colored with anilin colors by previously coloring the solution.

When bodies are sublimed, they usually assume the form of crystals in coming back to the solid form; for example, iodine and sulphur. When we evaporate down a solution containing two or more salts of different degrees of solubility, the least soluble crystallizes first, and may thus be separated from the more easily soluble ones.

This fact is taken advantage of in preparing common salt from sea water or salt springs. The common salt, being less soluble than the magnesium and potassium chlorides, bromides, or iodides, with which it is often associated, separates first, and may be skimmed off, leaving the others in the **mother liquor**—the name given to the liquid from which crystals are obtained.

When a substance crystallizes from a solution, the crystals, if perfect, are nearly free from impurities. We therefore take advantage of this method to purify substances.

Water of Crystallization.—Most substances, when they separate from a solution, take with them a certain definite amount of water as a necessary part of the crystal. This water is known as **water of crystallization.** The crystals of a given substance, when deposited at the same temperature, always contain the same amount of water. Thus, the crystals of copper sulphate contain five molecules of water for one of the salt, and the formula of the crystal is written thus:

$CuSO_4.5H_2O$ or $CuSO_4.5Aq.$

Ferrous sulphate crystals have the formula	$FeSO_4.7H_2O$
Sodium carbonate " " "	$Na_2CO_3,10H_2O$
Alum " " "	$K_2Al_2(SO_4)_4.24H_2O$

A few salts have different amounts of water of crystallization when separated at different temperatures. Thus crystals of manganous sulphate have the formula,

$MnSO_4.\ 7H_2O$	when crystallized below	6°C.	(42.8°F.)
$MnSO_4.\ 5H_2O$	" " between	7° and 20°C.	(44° and 68°F.)
$MnSO_4.\ 4H_2O$	" " "	20° and 30°C.	(68° and 86°F.)

The crystalline forms in these three cases are entirely different, showing that the molecules of water are necessary to the form of the crystal. The water in these cases, is held by a feeble force, and may generally be driven off by exposing the crystal to a temperature of 100° C. (212° F.) in a dry atmosphere, when the crystals fall to powder. In some cases the crystals lose their water at ordinary temperatures and crumble to a powder. They are then said to **effloresce.** On the other hand, some dry substances, when exposed to the air, absorb water. They are then said to **deliquesce**; such a body is said to be **deliquescent** or **hygroscopic.**

Silver nitrate ($AgNO_3$), and a few other salts, crystallize without water of crystallization.

Forms of Crystals.—A great variety of crystalline forms are met with, but for convenience of study all may be classed in six systems. These systems are based upon the number, length, and inclination of certain imaginary lines called axes, passing through the centre of the crystals and connecting opposite parallel sides, or opposite angles. (See Fig. 36.)

The following figures represent a few of the most common and simpler forms of crystals met with, and the most of those spoken of in the following pages:

Fig. 36.

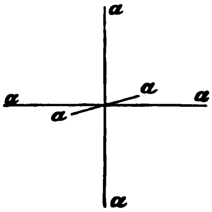
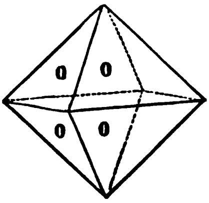
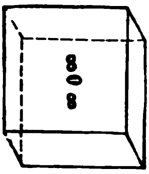


Fig. 37.



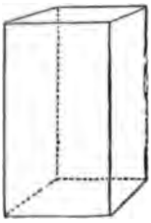
REGULAR OCTAHEDRON.

Fig 38.



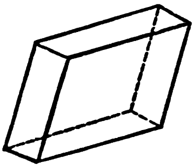
CUBE.

Fig. 39.



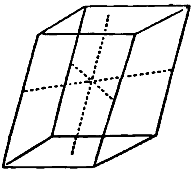
PRISM.

Fig. 40.



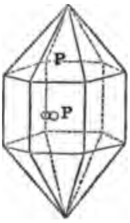
OBLIQUE RHOMBIC PRISM.

Fig. 41.



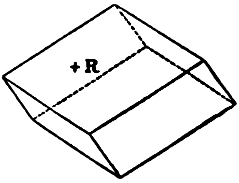
RHOMBOIDAL PRISM.

Fig. 42.



HEXAGONAL PRISM.
Modified by Pyramid.

Fig. 43.



RHOMBOHEDRON.

PART II.

THEORETICAL CHEMISTRY.

Molecules.—A **molecule** has been defined as a collection of atoms held together by chemism or affinity, in such a way as to neutralize their tendency to combine with outside atoms.

Hence, a molecule may be defined as the smallest portion of matter that can remain in the free or uncombined state. When the atoms comprising a molecule are of the same kind, it is said to be **elemental** or **simple**; when of different kinds, it is called a **compound molecule.**

When, by chemical means, we cause a re-arrangement of the atoms of compound molecules, we may obtain two or more kinds of elementary molecules; but with elementary molecules we only obtain one kind. We may illustrate this by the following formulæ:—

Let **ab** and **ab** represent two compound molecules. By a re-arrangement we may have **aa** and **bb**. If we take **aa** and **aa** we shall not be able to obtain anything else but **aa** and **aa**.

If in the molecules represented by HOH and HOH, we cause the re-arrangement by a strong electric current, we shall have **HH, HH** and **OO,** or two kinds of molecules entirely different from the original molecules and from each other.

If, on the other hand, a current of electricity be caused to pass through either HH + HH, or OO + OO, we will only obtain HH and HH, or OO and OO. By this and other methods known to chemists, about 73 elemental molecules or different kinds of atoms have been discovered. By a **chemical element,** then, we mean a substance that has never been found to contain more than one kind of atoms; and a compound body is one that has been shown to contain more than one kind of matter or atoms. These 73 different molecules or atoms have each received a separate name; the name of the molecule and that of the corresponding element being the same. These names are given in the first column of the following table:—

THE CHEMICAL ELEMENTS.

Name.	Symbol.	Equivalence.	Specific Gravity.	§ Atomic Weight. O = 16	‡ Atomic Weight. H = 1	Electrical State.
1 Aluminum .	Al	IV, $(Al)_2$ vi	2.5	27.0	27.04	+
2 Antimony . (Stibium)	Sb	III, *V*	6.7	120	119.6	—
3 Argon . . .	A	(?)	D=19.9	39.8		
4 Arsenic . .	As	III, *V*	5.8 gas 150	75 (L=13.44)†	74.9	—
5 Barium . . .	Ba	II	4	137.43	136.9	+
6 Beryllium . (Glucinium)	Be	II	2.15	9	9.03	
7 Bismuth . .	Bi	III, *V*	9.8	209	208.9	+
8 Boron . . .	B	III	2.63	11	10.9	—
9 Bromine . .	Br	I, *III*, *V*, *VII*	3.2 D*=80	79.95 (L=7.17)	79.76	—
10 Cadmium . .	Cd	II	8.6 D=56	112	111.5	+
11 Cæsium . .	Cs	I	...	132.9	132.7	+
12 Calcium . .	Ca	II	1.57	40	39.91	+
13 Carbon . . .	C	II, IV	D.3.3 G.2.3	12	11.97	—
14 Cerium . . .	Ce	II, *IV* (Ce_2) vi	6.62	140.2	139.9	+
15 Chlorine . .	Cl	I, *III*, *V*, *VII*	35.5	35.45	35.37	—
16 Chromium .	Cr	II, IV, (Cr_2) vi	6.8	52.1	52.0	—
17 Cobalt . . .	Co	II, IV, $(Co)_2$ vi	8.9	59.5	58.6	+
18 Columbium . (Niobium)	Cb	V	...	94.	93.7	—
19 Copper . . .	Cu	II, $(Cu)_2$ ii	8.9	63.6	63.18	+
20 Erbium . . .	E	II, (Er_2) vi	...	166.3	166.0	+
21 Fluorine . .	F	I	19	19	19.0	—
22 Gadolinium .	Gd			156.1		+
23 Gallium . .	Ga	III, (Ga_2) vi	6	69	69.9	+
24 Germanium .	Ge	II, IV	5.5	72.3	72.3	
25 Gold (Aurum)	Au	I, III	19.3	197 3	196.7	+
26 Hydrogen (or Hydrogenium)	H	I	D=1	1.008 (L= 0896 gm)	1.0	+
27 Indium . . .	In	II, (In_2) vi	7.4	113.7	113.6	+
28 Iodine . . .	I	I, III, *V*, *VII*	D=127 4.9	(L=10.38) 126.85	126.53	—
29 Iridium . . .	Ir	*II*, IV, *VI*	21.1	193.1	192.5	+
30 Iron (Ferrum)	Fe	II, IV, (Fe_2) vi	7.8	56	55.88	+
31 Lanthanum .	La	III	6.1	138.2	138.2	+
32 Lead (Plumbum)	Pb	II, IV	11.3	206.95	206.4	+
33 Lithium . .	Li	I	.6	7.02	7.01	+
34 Magnesium	Mg	II	1.7	24.3	24.3	+
35 Manganesium	Mn	II, IV, (Mn_2) vi	8	55.	54.8	+

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* D = Density of gas or vapor.

† L = Weight of 1 litre of vapor or gas

‡ U. S. P., from Meyer and Seubert.

§ See Jr. Am. Chem. Soc., Mar 1895, p. 212.

NAME.	SYMBOL.	EQUIVALENCE.	SPECIFIC GRAVITY.	ATOMIC WEIGHT. O = 16	ATOMIC WEIGHT. H = 1	ELECTRICAL STATE.
36 Mercury (Hydrargyrum)	Hg	(Hg_2)II, II	13.6 (D = 100)	200 (L = 8.96)	199.8	+
37 Molybdenum	Mo	*II*, *IV*, VI	8.6	96	95.9	—
38 Neodymium .	Nd	II	...	140.5	...	+
39 Nickel . . .	Ni	II, *IV*, (Ni_2) VI	8.8	58.7	58.6	+
40 Nitrogen . .	N	*I*, III, *V*	14	14.03	14.01	—
41 Osmium . .	Os	*II*, IV, *VI*, *VIII*	21.4	190.8	190.3	+
42 Oxygen . .	O	II	16	16 (L = 1.43)	15.96	—
43 Palladium .	Pd	*II*, IV	11.16	106.5	106.35	+
44 Phosphorus .	P	III, V	2.2 1.83 D = 62	31	30.96	—
45 Platinum . .	Pt	*II*, IV	21.5	195	194.3	+
46 Potassium (Kalium) .	K	I	.86 D = 39.1	39.11 (L = 3.5)	39.03	+
47 Praseodymium	Pr	II	...	143.5	...	+
48 Rhodium . .	Rh	*II*, IV	11	103	102.9	+
49 Rubidium .	Rb	I	...	85.5	85.2	+
50 Ruthenium .	Ru	*II*, IV, *VI*, VIII	11.4	101.6	101.4	+
51 Samarium .	Sm	III, V	...	150	149.62	
52 Scandium . .	Sc	III, (Sc_2) VI	...	44	43.97	
53 Selenium . .	Se	II, *IV*, *VI*	4.8	79	78.87	—
54 Silicon . . .	Si	*II*, IV	2.6	28.4	28.3	—
55 Silver . . . (Argentum)	Ag	I	10.5	107.92	107.66	+
56 Sodium (Natrium) .	Na	I	.97 D = 23	23.05 (L = 2.06)	23.0	+
57 Strontium .	Sr	II, *IV*	2.54	87.66	87.3	+
58 Sulphur . .	S	II, *IV*, *VI*	2 D = 32	32.06 (L = 2.86)	31.98	—
59 Tantalum . .	Ta	III, V	10.78	182.6	182.0	—
60 Tellurium .	Te	II, *IV*, *VI*	6.6	125	125.0	—
61 Terbium . .	Tb	III	...	160	159.1	+
62 Thallium . .	Tl	I, *III*	11.8	204.18	203.7	+
63 Thorium . .	Th	IV	7.9	232.6	231.9	+
64 Thulium . .	Tu		...	170.7		+
65 Tin (Stannum)	Sn	*II*, IV	7.3	119	118.8	+
66 Titanium . .	Ti	*II*, IV	...	48	48.0	—
67 Tungsten . . (Wolfram)	W	II, *IV*, VI	17.6	184.9	183.6	—
68 Uranium . .	U	II, IV, (Ur_2) VI	18.4	239.6	238.8	+
69 Vanadium .	V	III, V (V_2) VI	...	51.4	51.1	—
70 Ytterbium .	Yb	III	...	173	172.6	
71 Yttrium . .	Yt	III	4.8	89.1	88.9	+
72 Zinc	Zn	II	7 D = 32.5	65.3	65.1	+
73 Zirconium .	Zr	*II*, IV	4.1	90.6	90.4	+

NOTE.—A number of elements have been announced within the past few years, whose names do not appear in this table. Some of them have already been found to be compounds, and others will probably be found to be such when further studied.

PROPERTIES OF MOLECULES.

Molecular Weights.—Molecules, whether elementary or compound, must have a definite size and weight. The absolute weight of molecules and atoms is of no practical value to the chemist, but the comparative weights of molecules we shall find to be of vast importance. The physical properties of bodies, as color, hardness, ductility, etc., are determined by the properties of the molecules composing them. In weighing molecules we use the lightest known atom as the unit of weight. This atom is that of hydrogen. The relative weights of molecules have all been measured, and in expressing these weights our numbers express how many times heavier the molecule is than the hydrogen atom. Thus the molecular weight of oxygen is 32. That is, the molecule of oxygen weighs as much as 32 atoms of hydrogen.

Molecular weight, then, is the weight of a molecule as compared with the weight of the hydrogen atom.

Avogadro's or Ampère's Law.—This law was first enunciated by Avogadro, an Italian physicist, in 1811, and was reproduced by Ampère, a French physicist, in 1814. The law has already been stated (see gaseous state) as follows:—**Equal volumes of all true gases, when at the same temperature and under the same pressure, contain the same number of molecules.** That is to say, a litre of any given gas, under the same conditions of temperature and pressure, always contains the same number of molecules, whatever the nature or composition of the molecules composing the gas. As a natural conclusion from this law, we have the following: **First.—Gaseous molecules always occupy the same space;** *i. e.*, the molecule, together with the intervening space, always occupies the same volume. **Second.**—Since the same volume contains the same number of molecules, it follows that **the weights of equal volumes of any two gases** (under like conditions as above) **are the weights of the same number of molecules. Hence, the two weights will stand in the same proportion to each other as the weights of their respective molecules.**

Thus, suppose equal volumes of hydrogen and oxygen gases, large enough to contain 10,000 molecules each; the weights of these gases will be in the one case 10,000 times the weight of one molecule of hydrogen, and in the other 10,000 times the weight of one molecule of oxygen, and these numbers must be to each other as the weight of 1 molecule of hydrogen to 1 molecule of oxygen. This law is the basis of many of our modern chemical notions. It is to chemistry what Newton's law of gravitation was to the science of astronomy. This is not the place to enter into the discussion of the proofs of this law. Suffice it to say, that it rests on about as strong proof as any other law of physics or chemistry, or as the law of gravitation itself.

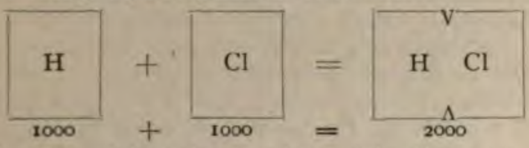
If we accept the **mechanical** theory of gases as given in pp. 20, 21, and 23, the law of Avogadro is capable of mathematical proof. The evidence in its favor has become so strong that it is now accepted by nearly all chemists as a fact.

Number of Atoms in Elemental Molecules.—We may determine the number of atoms in many elementary molecules by a simple application of Avogadro's law to well-known experiments.

This demonstration may be illustrated by reference to the behavior of the two gases, chlorine and hydrogen.

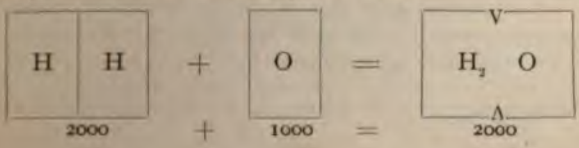
Into a glass tube inverted over mercury, put equal volumes of the two gases, and allow the apparatus to stand in diffused light. After some hours, the greenish color of the mixture will have entirely disappeared, the gases having combined to form the colorless hydrochloric acid. The mercury stands at the same height in the tube as at the beginning of the experiment. The volume of the hydrochloric acid is therefore just equal to the combined volume of both constituents. (See p. 115.)

Let the following diagram represent this combination:—



Since the volume of the hydrogen and that of the chlorine are equal, it is clear, from the law of Avogadro, that the number of molecules of each will be the same; also, that the number of molecules of the hydrochloric acid gas must be equal to the sum of the molecules of the two gases used. Suppose, for illustration, that the volume of hydrogen taken contained 1000 molecules; then there will be 1000 molecules of chlorine, and 2000 molecules of hydrochloric acid, the volume of this gas being twice that of hydrogen. Each of the 2000 molecules of hydrochloric acid must contain at least an atom of hydrogen and one of chlorine; hence, 2000 atoms of each of these elements have been derived from 1000 molecules of the same, and therefore each molecule must have furnished at least two atoms.

Experiments quite as decisive have been made to show that in water the 2 volumes of hydrogen and 1 volume of oxygen produce only 2 volumes of water-vapor. Thus:—



By the same reasoning we may show that each molecule of oxygen contains two atoms; also that each molecule of water must contain *two* atoms of hydrogen to one of oxygen, instead of *one*, as was formerly taught.

Most of the molecules of elementary substances contain two atoms; or, in other words, are diatomic. Argon, mercury, cadmium, zinc, and barium, however, contain but one atom in each molecule. Oxygen, as **ozone,** contains three atoms. Phosphorus and arsenic contain four atoms, but at a white heat these break up into simpler molecules. Sulphur at lower temperatures seems to contain six, while at higher temperatures it contains only two.

Some molecules which at ordinary temperatures contain two atoms, break up or **dissociate,** as it is termed, at very high temperatures. Thus chlorine, bromine, and iodine, which at a moderate heat are diatomic, at a very high temperature, 800° C., begin to dissociate, and become monatomic at the strongest furnace heat. Many compounds do the same thing. (Hg_2Cl_2,N_2O_2,-N_2O_4). The law of Ampère is, therefore, true only at moderate temperatures.

Molecular Weight, Determined by the Law of Avogadro.—It has just been shown that the molecule of hydrogen is composed of two atoms. We have already defined molecular weight as the weight of a molecule in units of hydrogen atoms. It may also be defined as the sum of the weights of its constituent atoms. The molecular weight of hydrogen is therefore $1 + 1$, or 2. Suppose, for example, we weigh equal volumes of hydrogen and oxygen gases under like conditions of temperature and pressure, and find the weights to be respectively 1 and 16 grammes. It follows that the molecules of these gases are to each other as 1 to 16, for, according to the law, each contains the same number of molecules. As the molecular weight of hydrogen has been shown to be 2, it follows that the molecular weight of oxygen must be 32, for 32 bears the same ratio to 2 that 16 does to 1. $1 : 16 :: 2 : 32$. From this it will be seen that the molecular weight of oxygen is twice its density; *i. e.*, its specific gravity as compared with hydrogen. The same reasoning applies to all other gases, whether elemental or compound, and we may state this fact as follows:—**The molecular weight of any body is twice its density in the gaseous state.** The converse of this statement is also true, viz.: **the density of a gas is one-half its molecular weight.** For methods of determining molecular weights, see Part IV, p. 298.

PROPERTIES OF ATOMS.

Definition.—An atom is the smallest conceivable portion of matter. It is the smallest portion of an element that can enter into the formation of a molecule, or take part in a chemical reaction.

The student should strive to clearly comprehend the difference between a molecule and an atom. The former is a collection of the latter held together by an attraction called chemism or chemical affinity. Molecules are destructible; they may be broken up and their properties destroyed. The atom, on the other hand, is an indestructible solid particle, whose properties, so far as we know, are never destroyed.

Atomic Weight.—Atoms differ from one another in their weight, and the quality and the quantity of their combining power. Further than this we have no certain knowledge of their properties.

The weight of an atom of any given element is always the same. In weighing atoms we do not take the absolute weight, but the relative weight, using the hydrogen atom as the unit. The **atomic weight** of any element expresses the number of times its atom is heavier than the atom of hydrogen. The atomic weight of oxygen is 15.96; *i. e.*, the atom weighs 15.96 (approximately 16) times as much as the atom of hydrogen. The atomic weights of the elements will be found in the table, p. 80.

Quality of Combining Power. Polarity of the Atoms.—We have seen (p. 70) that when a current of electricity is sent through a solution of a metallic salt, the metal collects about the negative electrode, while the non-metallic part of the salt appears at the positive.

Most metallic compounds are capable of decomposition by electrolysis, and the molecule seems to be divided into two parts, one of which is attracted to the positive and the other to the negative electrode. We have seen (p. 46) that two bodies, similarly polarized, repel each other, while bodies oppositely polarized attract each other. We conclude, therefore, that those atoms which are attracted by the negative pole of the galvanic battery are positively polarized, while the others are negatively polarized. This is what is meant by the difference in the quality of combining power. Positive and negative, as applied to the polarity of atoms, is not absolute, but relative; and the polarity of an atom may be changed, by the inducing action of another atom, from positive to negative, or *vice versa.* As a general rule, the metallic atoms are positive, and the non-metallic negative.

When several atoms are brought into contact with one another, those having similar polarity repel one another, as do other bodies that are of like polarity, while those having a different polarity attract one another; hence, union or combination can only take place between atoms that are unlike in their electrical polarity.

In the following table the elements are so placed that each one is electro-negative to those below, and electro-positive to those above it. In this table, silicon, and those which follow it, are positive to titanium, and iron is positive to nickel.

ELECTRO-CHEMICAL SERIES.

Negative End—.
Oxygen.
Sulphur.
Nitrogen.
Fluorine.
Chlorine.
Bromine.
Iodine.
Selenium.
Phosphorus.
Arsenic.
Chromium.
Vanadium.
Molybdenum.
Tungsten.
Boron.
Carbon.
Antimony.
Tellurium
Tantalum.
Columbium.
Titanium.
Positive End +.

Negative End—.
Silicon.
Hydrogen.
Gold.
Osmium.
Iridium.
Platinum.
Rhodium.
Ruthenium.
Palladium.
Mercury.
Silver.
Copper.
Uranium.
Bismuth.
Tin.
Indium.
Lead.
Cadmium.
Thallium.
Cobalt.
Nickel.
Positive End +.

Negative End—.
Iron.
Zinc.
Manganese.
Lanthanum.
Didymium.
Cerium.
Thorium.
Zirconium.
Aluminum.
Erbium.
Yttrium.
Glucinum.
Magnesium.
Calcium.
Strontium.
Barium.
Lithium.
Sodium.
Potassium.
Rubidium.
Cæsium.
Positive End +.

Quantity of Combining Power.—By an analysis of a large number of compounds of hydrogen with other elements, it has been found that while chlorine combines with it in the proportion of its atomic weight, *i. e.*, 1 part by weight of hydrogen to 35.5 parts of Cl,

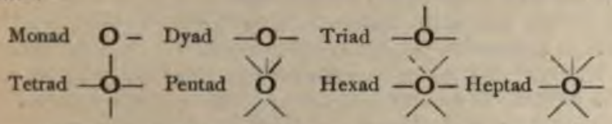
16 parts of Oxygen combine with 2 parts of H,
14 " " Nitrogen " " 3 " " H,
12 " " Carbon " " 4 " " H,

and so on; so that the power of the atoms to attract and combine with hydrogen is not alike in all cases. This is expressed by saying that the **equivalence,** or **quantivalence,** of the atom in question is 1, 2, 3, 4, 5, 6, or 7, according as it will attach to itself, be exchanged for, or take the place in a molecule of 1, 2, 3, 4, 5, 6, 7, atoms of hydrogen or their equivalent.

The chemical equivalent of an atom, is an atom which can take its place in a molecule. Atoms are divided into monads, dyads, triads, tetrads, pentads, hexads, or heptads, according as they can fix 1, 2, 3, 4, 5, 6, or 7 atoms of hydrogen, or their equivalent. Univalent, bivalent, trivalent, etc., are adjectives used to express the valence of an atom.

A monad is equivalent to a monad.
" dyad " " to 2 monads.
" triad " " to 3 monads, or 1 monad and 1 dyad.
" tetrad " " to 4 monads, 2 dyads, or 1 monad, and 1 triad.
A pentad " " to 5 monads, a tetrad and 1 monad, a triad and 2 monads, or 2 dyads and 1 monad.

The valence of an atom is often indicated to the eye by dashes, thus:—



It will be seen that the hydrogen atom is the unit of comparison for combining powers, or valences, and the dashes represent the number of **bonds** or **points of attraction,** or **poles** of the **atomic magnet.** The valence of an atom may also be expressed by a Roman numeral placed above and to the right, thus:—H^{I}, O^{II}, Cl^{III}, C^{IV}, etc.

CHEMICAL NOTATION.

Symbols and Formulæ.—In representing atoms and molecules to the eye, we make use of a series of symbols derived from the names of the elements themselves. This is usually the initial letter of the English or Latin name, or in case two or more names begin with the same letter, the initial with some other characteristic letter. Thus, on reference to the table on page 80, we see B, Ba, Bi, Br, representing the atoms of boron, barium, bismuth, and bromine respectively. In this book, a symbol is never used to represent the element in general, but a symbol always represents an atom, with all its properties, and nothing else.

Formulæ.—A formula is the sign of a molecule. It, therefore, represents a definite weight—the molecular weight; and in the case of gases, always the same volume. Formulæ are made up of symbols, as a molecule is made up of atoms; and the atoms composing a molecule are all represented by symbols in the formula. Thus: HCl is a formula representing a molecule containing one atom or 1 part of hydrogen, and one atom or 35.5 parts by weight of chlorine.

In writing formulæ, we write the symbols composing the molecule in juxtaposition, beginning with the more electro-positive. Thus: $KOCl$, HBr, etc.

Multiplication of Molecules and Atoms.—When we wish to represent more than one atom, we use a small numeral at the right hand lower corner of the symbol; thus, O_2, represents 2 atoms of oxygen, or, since the molecule of oxygen contains two atoms, this also represents the molecule. As_4 represents 4 atoms of arsenic, or, since the molecule of arsenic contains four atoms, it is also the formula of a molecule of arsenic.

When we wish to represent more than one molecule of a substance, we use full-sized numerals placed before the formula. Thus, $2H_2O$ represents two molecules, each of which is composed of two atoms of hydrogen and one of oxygen. Or, we may enclose the formula in a parenthesis, and place a small numeral at the right hand lower corner, thus: $(H_2O)_2$. Examples:—

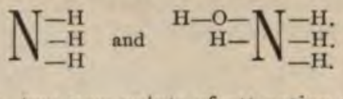
H_2SO_4 represents 1 molecule, containing 2 atoms of hydrogen, 1 of sulphur, and 4 of oxygen.

$5H_2SO_4$ represents 5 molecules of the same substance.

$3NH_4NO_3$ represents 3 molecules, containing in each molecule two atoms of nitrogen, 4 atoms of hydrogen, and 3 atoms of oxygen; 27 atoms in all.

$2K_2Al_2(SO_4)_4$ represents two molecules, containing in each molecule 2 atoms of potassium, 2 atoms of aluminum, 4 atoms of sulphur, and 16 atoms of oxygen; 48 atoms in all.

As the symbols always represent the atomic weights, we may reduce any formula to figures, or find its molecular weight, by adding together the weights represented by the symbols composing it. Let it be desired to find the molecular weight of H_2SO_4. By reference to the table on page 80, it will be seen that $H_4 = 2$, $S = 32$ and $O_4 = 4 \times 16 = 64$. By adding together these three numbers we obtain 98, the weight of the molecule. An **empirical formula** is one which merely gives the kind and molecule of the water and becomes NH_4OH. If we represent the two moleculces graphically, we have,



As will be seen, two new points of attraction have made their appearances upon the nitrogen atom. A large number of such cases are known, and the explanation is as follows:—

The full equivalence of nitrogen is pentad. In the compound H_3N, for some unknown reason, two poles of the atomic magnet neutralize each other, and so the combining power of the atom is lessened by two. This increase or diminution of combining power always takes place in pairs, so that a dyad may become a tetrad, but not a triad. A monad may become a triad, or a pentad, but never a dyad or tetrad.

Other Signs Used in Writing.—A plus sign between two formulæ indicates that the substances, whose molecules they represent, are brought together.

The **minus sign** indicates that the molecule following it is abstracted from the preceding one. The **sign of equality** is used to indicate that what follows is the result of some change that has taken place. $HCl + AgNO_3 = HNO_3 + AgCl$ shows that the molecules represented by the first two formulæ have been brought together, and that a change has taken place resulting in the formation of the two last.

Compound Radicals.—A radical or root of a series of compounds is a characteristic atom or group of atoms running through all of them, like a **root** in language. Thus the interrogative root **wh** runs through all that class of words, as **who, which, when, what, etc.** So, in chemical compounds we have a large number of potassium compounds, in which the atom K appears as the characteristic atom: As KNO_3, $KClO_3$, K_2CO_3, K_2SO_4, and KCl. It is therefore called the root or radical of these compounds. A single atom, which forms a series of characteristic compounds, is called a **simple radical.**

Sometimes instead of being a single atom, it is a group of atoms that is found to be the characteristic of a series of compounds. Thus, we have: $(NH_4)NO_3$, $(NH_4)Cl$, $(NH_4)NO_2$, $(NH_4)_2S$, etc., in which the characteristic radical is a group of atoms, or is a **compound radical.**

A compound radical may be regarded as a group of atoms which behaves like a simple radical, or single atom. Like the single atom, it exists only in combination with another atom or group of atoms, for its bonds or points of attraction are not satisfied unless it be in combination. Compound radicals, like atoms, may be positive or negative. Each compound radical has a definite equivalence, like the atoms. Some of them have received arbitrary names which do not express their composition, and in most cases end in yl. Thus, $(PO)'''$ phosphoryl, $(H\text{-}O\text{–})'$ hodroxyl, $(CO)''$ carbonyl, $(CH_3)'$ methyl, $(C_2H_5)'$ ethyl, $(H_4N)'$ ammonium, $(CN)'$ cyanogen, $(NH_2)'$ amidogen. The last three are exceptions to the rule as to the ending.

In writing the formula of these compound radicals, they may be regarded for the time as atoms of a compound nature. If we wish to represent that several similar compound radicals enter into the same molecule, we enclose the formula in a parenthesis, and as with atoms use the numerals thus, $(NH_4)_2CO_3$, $Fe_2(OH)_6$.

In the foregoing table will be found the more important elements arranged according to both quality and quantity of combining power. The elements at the top of the table are negative to all below them; and those at the bottom are positive to all above. They are also divided into monad, dyad, triad, etc., some appearing in two or even three columns, because of their change in equivalence. In the second table will be found the more common atomic groups, with the names of the classes of compounds they form, arranged, as far as possible, in the same order as the elements. In regard to their electrical order, less certainty exists than with the elements.

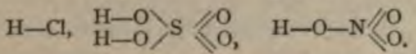
COMPOUND MOLECULES.

Compound Molecules Classified.—The system of nomenclature now in use for naming chemical compounds is based upon the composition and properties of the bodies in question; and the name of the body is intended to express our idea of its chemical composition. Homogeneous bodies are supposed to be made up of a collection of similar molecules; hence, a formula which represents the composition of a single molecule really represents the composition of the mass. In applying names to compounds, we apply the name to the molecule as well as the mass.

Compound bodies may be divided into two classes: 1st, those whose molecules are composed of two kinds of atoms or radicals, called **binary compounds,** and, 2d, those whose molecules are composed of three or more kinds of atoms or radicals, called

ternary molecules. Examples: NaCl, KBr, $MgCl_2$, and $(NH_4)Cl$ are examples of binary molecules. $KClO_3$, K_2SO_4, $CaCO_3$, $(NH_4)NO_3$, and $Ba(NO_3)_2$, are examples of ternary molecules.

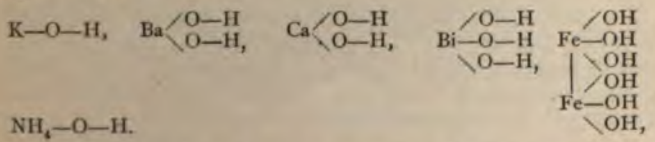
Acids, Bases, and Salts.—Ternary molecules are divided into **acids, bases,** and **neutrals** or **salts.** An **acid** is a substance which usually possesses a sour taste, corrodes the metals with the evolution of hydrogen and the formation of salts, changes blue vegetable colors to reds, and neutralizes the caustic properties of alkalies by forming salts with them. All acids contain hydrogen which can be replaced by a metal. This hydrogen is united to the remaining portion of the molecule, either directly, as in binary acids, or by a linking atom, usually oxygen, as represented by the following graphic formulæ:



$$H{-}Cl,\quad \begin{matrix}H{-}O\\H{-}O\end{matrix}\!\!>S\!\begin{matrix}{=}O\\{=}O,\end{matrix}\quad H{-}O{-}N\!\begin{matrix}{=}O\\{=}O.\end{matrix}$$

The replaceable hydrogen of an acid is called **basic hydrogen,** and the number of such atoms determines the **basicity** of the acid. A dibasic acid, for example, is one containing two atoms of basic hydrogen, a tri-basic acid three, a tetra-basic acid four, and so on. When the linking atom of these ternary acids is oxygen, the name of **ox-acids** is applied to them. The term **sulpho-acids** is applied to those containing linking sulphur. A **base** has properties which in many respects are opposed to and neutralize the effects of acids. They restore the vegetable blue colors reddened by acids, they neutralize the sour taste, and they react upon acids to form salts, with the elimination of water. The strong bases have a caustic action upon the tissues, and decompose the fats, with which they form soaps.

A **base** may be defined as a compound whose molecule is composed of a positive atom, or group of atoms, united by linking oxygen to hydrogen.* The positive atom is metallic in inorganic bases. As:—



$$K{-}O{-}H,\quad Ba\!\begin{matrix}/O{-}H\\ \backslash O{-}H,\end{matrix}\quad Ca\!\begin{matrix}/O{-}H\\ \backslash O{-}H,\end{matrix}\quad Bi\!\begin{matrix}/O{-}H\\ {-}O{-}H\\ \backslash O{-}H,\end{matrix}\quad \begin{matrix}Fe\!\begin{matrix}/OH\\{-}OH\\ \backslash OH\end{matrix}\\ |\\ Fe\!\begin{matrix}/OH\\{-}OH\\ \backslash OH,\end{matrix}\end{matrix}$$

$$NH_4{-}O{-}H.$$

In the last formula we have an example of a compound radical united to H by O. The inorganic bases are named **hydroxides** or **hydrates.**

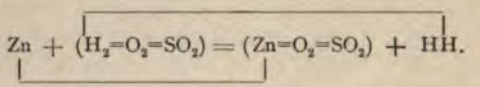
---

* This definition applies only to inorganic bases.

A **salt** molecule is composed of a positive radical united by linking oxygen to a negative radical. The radicals, in this case, as in acids and bases, may be either simple or compound. Thus:

$K—O—Cl$, $K—O—NO_2$, $Na_2=O_2=CO$, $Ba=O_2=SO_2$, $(NH_4)—O—NO_2$.

It is evident, also, that a salt may be formed by treating an acid with a metal, which replaces the hydrogen of the acid with metallic atoms.

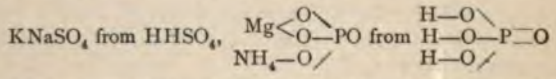


$$Zn + (H_2=O_2=SO_2) = (Zn=O_2=SO_2) + HH.$$

It may be regarded, then, as an acid whose replaceable hydrogen atoms have been replaced by positive atoms or radicals. In a dibasic acid, like $\begin{matrix}H—O\diagdown\\H—O\diagup\end{matrix}S\begin{matrix}\diagup O\\\diagdown O,\end{matrix}$ it is possible to replace one of the atoms of hydrogen and leave the other undisturbed. We thus have, for example, $\begin{matrix}H—O\diagdown\\K—O\diagup\end{matrix}S\begin{matrix}\diagup O\\\diagdown O,\end{matrix}$ which exhibits the properties, and answers to the definition of both a salt and an acid. It has acid properties by virtue of the replaceable hydrogen, and saline properties by virtue of the other chain in which the K has replaced H.

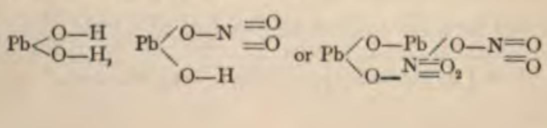
Such a body is called an **acid salt,** while the salts first mentioned, in which all the H atoms have been replaced by positive atoms, are called **normal salts.**

Double salts are formed by replacing a part of the hydrogen of the acid by one positive radical, and a part by another.



$$KNaSO_4 \text{ from } HHSO_4, \quad \begin{matrix}Mg<\begin{matrix}O\diagdown\\O—\end{matrix}PO\\NH_4—O\diagup\end{matrix} \text{ from } \begin{matrix}H—O\diagdown\\H—O—P=O\\H—O\diagup\end{matrix}$$

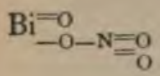
If a base or metallic oxide be treated with sufficient acid to neutralize it, a neutral salt is **usually** formed; but if the base or oxide be much in excess of what the acid would require to expel all its hydrogen, a basic salt will, in some cases, be formed according to the following formula:—

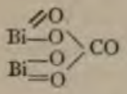


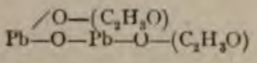
$$Pb<\begin{matrix}O—H\\O—H,\end{matrix} \quad Pb\begin{matrix}\diagup O—N\begin{matrix}=O\\=O\end{matrix}\\\diagdown O—H\end{matrix} \text{ or } Pb\begin{matrix}\diagup O—Pb\diagup O—N\begin{matrix}=O\\=O\end{matrix}\\\diagdown O—N\equiv O_2\end{matrix}$$

i. e., the acid radical will take the place of a part of its replaceable hydrogen, and leave a part of it; or a part of the excess of oxide will crowd into the molecule between the negative radical and the positive. Such bodies are called **basic** or **subsalts.**

The **subsalts** are seldom of definite chemical composition, often being mixtures of the oxide with the basic or even normal salt. Lead and bismuth are two metals especially liable to form basic salts.







NOMENCLATURE.

Naming of Chemical Compounds.— Rule. – Give the name of the positive radical first; then the name of the leading negative atom or radical with its termination changed to id* or ide in binaries, and to ite or ate in ternaries : ite denoting the lower, and ate the higher equivalence of the negative atom.

EXAMPLES.

$Na\,Cl$ = Sodium Chlorid or Chloride, — binary.
$Na\,NO_2$ = " Nitrite, — ternary.
$Na\,NO_3$ = " Nitrate, — "
$Ba\,Cl_2$ = Barium Chlorid or Chloride, — binary.
$Ca\,Br_2$ = Calcium Bromid or Bromide, — "
$Ba\,SO_3$ = Barium Sulphite, — ternary.
$Ba\,SO_4$ = " Sulphate, — "

As will be seen on inspection, the equivalence of the negative atom is indicated by the comparative amounts of oxygen which it holds. Compare $BaSO_3$, and $BaSO_4$; also $NaNO_2$ and $NaNO_3$. In compounds like the following—$SnCl_2$, $SnCl_4$, $CuCl_2$, Cu_2Cl_2, $HgCl_2$, Hg_2Cl_2, $FeCl_2$ and Fe_2Cl_6—where there are more

---

* The final *e*, in the spelling of the names of the binary compounds, is recommended to be dropped by the rules of the American Association for the Advancement of Science. For these rules, see Appendix. The reasons for retaining the established spelling in this edition will be found in the Preface.

1 BaO_2H_2
2 CaC_2O_4
3 $BiCl_3$
4 Na_2CO_3
5 $MgSO_4$
6 $Fe_2(SO_4)_3$
7 $AgNO_3$
8 $(NH_4)Cl$
9 HNO_3
10 Hg_2Cl_2
11 $PbCrO_4$
12 KI
13 K_2O
14 As_2O_3
15 Cu_2FeCy_6
16 $(NH_4)_2S$
17 As_2S_3
18 NH_4MgPO_4
19 $KHCO_3$
20 $SbCl_3$
21 $BiONO_3$
22 $Fe_3(Fe_2Cy_{12})$
23 $K(CN)S$
24 K_2CrO_4
25 $Fe_2(CrO_4)_3$
26 $Al_2(OH)_6$
27 KCy
28 ZnO
29 $SrCO_3$
30 $Sr(NO_3)_2$
31 $BaCl_2$
32 NH_4NO_3
33 $(NH_4)_2CO_3$
34 $KNaSO_4$
35 $NaHCO_3$
36 $Ca_3(PO_4)_2$
37 $Ca(PO_2H_2)_2$
38 $NaClO$
39 Bi_2O_3
40 O_2
41 $KClO_4$
42 $Pb_2O(C_2H_3O_2)_2$
43 $AgCl$
44 $AgBr$
45 NaF
46 NaI
47 KBr
48 $PbCl_2$
49 Fe_2Cl_6
50 $PtCl_4$
51 $AuCl_3$
52 MnO_2
53 K_2MnO_4
54 $Ba(NO_3)_2$
55 $MnSO_4$
56 $PbSO_4$
57 $Cu(C_2H_3O_2)_2$
58 $Ca(C_2H_3O_2)_2$
59 $Ca(OCl)_2$
60 $Fe_2(C_2H_3O_2)_6$
61 $Na(C_7H_5O_3)$
62 $Na(C_7H_5O_2)$
63 $K_2Mn_2O_8$ $KMnO_4$ (U. S. P.)
64 $K_2Cr_2O_7$
65 $(NH_4)_2C_2O_4$
66 $CaSO_3$
67 $Ca(C_4H_4O_6)$
68 $Na_2(C_4H_4O_5)$
69 Na_3AsO_3
70 Na_3AsO_4.

1 Barium Hydroxide.
2 Calcium Oxylate.
3 Bismuth Chloride.
4 Sodium Carbonate.
5 Magnesium Sulphate.
6 Ferric Sulphate.
7 Silver Nitrate.
8 Ammonium Chloride.
9 Hydrogen Nitrate. (Nitric Acid.)
10 Mercurous Chloride.
11 Lead Chromate.
12 Potassium Iodide.
13 Potassium Oxide.
14 Arsenious Oxide.
15 Copper Ferrocyanide.
16 Ammonium Sulphide.
17 Arsenious Sulphide.
18 Ammon. Magnesium Phosphate.
19 Acid Potassium Carbonate, or Potas. Bicarbonate.
20 Antimonous Chloride.
21 Bismuth Oxy nitrate.
22 Ferrous Ferricyanide.
23 Potassium Sulphocyanate.
24 Potasium Chromate.
25 Ferric Chromate.
26 Aluminic Hydroxide, or Hydrate.
27 Potassium Cyanide.
28 Zinc Oxide.
29 Strontium Carbonate.
30 Strontium Nitrate.
31 Barium Chloride.
32 Ammon. Nitrate.
33 Ammon. Carbonate.
34 Potassium Sod. Sulphate.
35 Hydrogen Sodium Carbonate.
36 Tri-Calcium Phosphate.
37 Calcium Hypophosphite.
38 Sodium Hypochlorite.
39 Bismuth Oxide.
40 Oxygen.
41 Potassium Perchlorate.
42 Basic Plumbic Acetate.
43 Silver Chloride.
44 Silver Bromide.
45 Sodium Fluoride.
46 Sodium Iodide.
47 Potassium Bromide.
48 Lead Chloride.
49 Ferric Chloride.
50 Platinic Chloride.
51 Gold Chloride.
52 Manganic Oxide.
53 Potassium Manganate.
54 Barium Nitrate.
55 Manganese Sulphate.
56 Lead Sulphate.
57 Copper Acetate.
58 Calcium Acetate.
59 Calcium Hypochlorite.
60 Ferric Acetate.
61 Sodium Salicylate.
62 Sodium Bensoate.
63 Potassium Permanganate.
64 Acid Potassium Chromate. (Potassium Bichromate.)
65 Ammonium Oxalate.
66 Calcium Sulphite.
67 Calcium Tartrate.
68 Sodium Malate.
69 Sodium Arsenite.
70 Sodium Arsenate.

Irregularities in Nomenclature.—In many medical and pharmaceutical works, the old style of making the negative precede the positive, with the preposition **of** between them, is still used. In this case **per** is used instead of **ic** or **ate**, and **proto** instead of **ite** or **ous**. These irregularities are becoming obsolete.

EXAMPLES.

	NEW NAME.	OLD NAME.
$SnCl_2$	= Stannous Chloride	or Protochloride of tin.
$SnCl_4$	= Stannic "	or Perchloride of tin.
Fe_2Cl_6	= Ferric "	or Perchloride of iron.
$Fe_2(SO_4)_3$	= " Sulphate	or Persulphate of iron.
Fe_2O_3	= " Oxide	or Per- or Sesquioxide of iron.
Hg_2I_2	= Mercurous Iodide	or Protiodide of mercury.
Hg_2Cl_2	= " Chloride	or Protochloride, mild chloride, or calomel.
$HgCl_2$	= Mercuric chloride	or Bichloride, corrosive sublimate.
HgO	= " oxide	or Red oxide of mercury.
Hg_2O	= Mercurous oxide	or Black oxide of " Protoxide of "

The **proto**-salts of iron are the **ferrous salts**, while the **per**-salts are the **ferric** salts.

The names of the oxides of the alkaline metals, the earths, and the alkaline earths are sometimes named as follows:—

Al_2O_3	Alumina.	CaO	Lime.
MgO	Magnesia.	K_2O	Potassa or Potash.
BaO	Baryta.	Na_2O	Soda.
SrO	Strontia.		

Some writers name those oxides of the non-metallic elements which dissolve in water to form acids, as though they were formed from the acids by abstracting one or more molecules of water.

Thus SO_2 is named Sulphurous Anhydride.
CO_2 " Carbonic "
N_2O_3 " Nitrous "
N_2O_5 " Nitric "
P_2O_5 " Phosphoric "

For, $SO_2 + H_2O = H_2SO_3$ = Sulphurous Acid.
$CO_2 + H_2O = H_2CO_3$ = Carbonic "
$N_2O_5 + H_2N = 2HNO_3$ = Nitric "
$P_2O_5 + 3H_2O = 2H_3PO_4$ = Phosphoric "
$SO_3 + H_2O = H_2SO_4$ = Sulphuric "

It is a common custom with some authors to use the numerals di, tri or ter, tetra and penta, to indicate the number of atoms of the element to whose name the numeral is prefixed.

Thus:—

	NEW NAME.	OLD NAME.
FeS_2	Ferric Disulphide	or Bisulphide of Iron.
Fe_2S	Diferrous Sulphide	or Sulphide of Iron.
Fe_2S_3	Ferric Sulphide	or Sesquisulphide of Iron.
FeS	Ferrous Sulphide	or Protosulphide of Iron.
CO_2	Carbon Dioxide	or Carbonic Acid.
PCl_3	Phosphorus Trichloride.	
PCl_5	" Pentachloride.	
$HgCl_2$	Mercuric Dichloride	or Bichloride of Mercury.

A few compounds are known by names which do not express their composition.

Thus:—

H_3N	Ammonia.	
CN	Cyanogen (symbol Cy).	
H_3Sb	Antimoniuretted Hydrogen	or Stibin.
H_3As	Arseniuretted "	or Arsin.
H_2S	Sulphuretted "	or Hydrosulphuric Acid.
H_3P	Phosphoretted "	or Phosphin.
H_4C	Light Carburetted "	or Marsh Gas.
H_4C_2	Heavy Carburetted "	or Olefiant Gas.

A glossary of obsolete and popular names, and those of some chemical compounds only occasionally met with, will be found in the Appendix.

Chemical Reactions and Equations.—All material bodies, under certain conditions, may undergo marked changes in properties. As the physical properties of bodies depend upon the properties of their molecules, any great change in these properties must depend upon a corresponding change in the molecules. In a homogeneous mass of matter, all molecules are alike; and any chemical change which we are able to produce in one molecule of such a mass, may, with certainty, be produced in all. Hence, by representing the changes which take place between two dissimilar molecules, we do, in reality, represent the changes taking place between the masses of which these molecules form a part. It is upon this principle that we represent chemical changes to the eye. When two substances, on being brought together, act upon each other, the mutual action between them is called a **reaction**.

A body which is added to another to cause such a change, is called a **reagent**. When a jet of coal gas is burned in the air, the reagents are the gas and the oxygen of the air. The **results** of the reaction are light and heat. The **products** of the reaction are the watery vapor and carbon dioxide which are produced. The **factors** entering into the reaction are oxygen and the compounds which compose the gas.

While all material molecules are more or less liable to undergo chemical change by the action of external agencies, some do so very readily, while others resist such change with considerable force. Chemical reactions are favored by anything that lessens cohesion, or favors the free movement of the molecules; as solution, pulverization, trituration, heat, light, and electricity.

Reaction between solids is always slow, and, in many cases, entirely wanting. If the solids are brought together in solution, the reaction takes place with readiness: if volatilized, still more readily. Reactions between gases, usually take place almost instantaneously throughout the mass, and, in many cases, with an explosion. Heat usually favors chemical action, and cold retards it. Light favors many kinds of chemical change, but does not affect all. Reactions, in the laboratory, are generally conducted in solutions. When the bodies are soluble in water, that liquid is generally selected; if not, some other solvent, such as ether, alcohol, chloroform, etc., is employed.

When two or more substances are brought together in solution, the action that will take place depends largely upon the following conditions, first formulated by Berthollet, and usually known as the **Laws of Berthollet**:—

1st. When two or more substances are brought together in solution, if by any rearrangement of the atoms a product can be formed which is insoluble in the liquid present, that substance will form and separate as a precipitate.

2d. When two substances are brought together in solution, if a gaseous body or one volatile of the temperature of the experiment, can form, it will form and escape as a gas or vapor.

Illustration. $BaCl_2 + Na_2SO_4 = ?$ By a rearrangement of these atoms, according to the principles stated in preceding articles, there can only form $BaSO_4$ and $2NaCl$. The latter of these is soluble in water, while the former is not; hence, $BaSO_4$ will always separate from this mixture.

$Zn + 2HCl = ZnCl_2 + H_2$. Here, by changing the places of the two postives, hydrogen is set free, and escapes.

The above laws apply to insoluble or volatile substances only.

When two acids in solution are made to act upon one base, or two bases upon one acid, to produce soluble non-volatile substances, the base in the first instance divides itself between the two acids, or in the second instance the acid is divided between the two bases. That is, if a solution of sodium hydroxide be treated with an excess of nitric and hydrochloric acids, both sodium nitrate and chloride are produced; or if sulphuric acid be treated with a mixture of sodium and potassium hydroxides more than sufficient to saturate the acid, both sulphates are produced. The quantities of each salt produced will depend upon the relative quantities of the two acids or two bases present, and the relative affinities between the acids and bases.

In diluted solutions of the above compounds, nitric and hydrochloric acids were found to be the strongest of the mineral acids, while hydrobromic, hydriodic, sulphuric, phosphoric, oxalic, and acetic acids follow in the order named. The avidity of nitric and hydrochloric acids for sodium was found to be twice that of sulphuric acid, or, when sodium sulphate is treated with excess of nitric acid, the following reaction takes place:—

$$2Na_2SO_4 + 4HNO_3 = Na_2SO_4 + 2NaNO_3 + H_2SO_4 + 2HNO_3.$$

As matter is indestructible, it follows that there can be neither loss nor gain in the weight of the matter taking part in a reaction. The sum of the weights of the factors entering into a reaction, must, therefore, be equal to the sum of the weights of the products coming from it. Hence, if we place the sum of the formulæ of the factors equal to the sum of the formulæ of the products of any reaction, it must always form a true equation. In writing out representations of chemical reactions, the student should remember the following rules:—

1st. **Positives** combine with **negatives** and not with **positives.**

2d. Every member of the equation must represent a whole molecule, or a number of molecules.

3d. The equivalences of the atoms and radicals must all be saturated according to the rules laid down under **equivalence.**

4th. An **acid** and a **base** cannot exist in the same solution. They are incompatibles, and neutralize each other.

5th. The strongest acids generally select the strongest bases, except in cases where this is modified by Berthollet's laws. Compound radicals, as a rule, remain as such in the products.

To write chemical equations, place the formulæ of the factors connected by a plus sign, equal to the formulæ of the products, also connected by a plus sign. Now take such a number of molecules as factors that only whole molecules can be produced in the products.

EXAMPLES.

$$\underset{\substack{\text{Silver}\\\text{Nitrate.}}}{\overset{+}{Ag}\ \overset{-}{NO_3}} + \underset{\substack{\text{Sodium}\\\text{Chloride.}}}{\overset{+}{Na}\ \overset{-}{Cl}} = (?)$$

We first determine which are positive and which are negative radicals. The metals are positive, and the non-metallic radicals are negative, as indicated by the signs above the symbols.

We next cause the positive radicals to exchange places, whence we have Ag Cl and Na NO_3.

On referring to the table of equivalences (page 91), we find all these radicals to be **monad**, and therefore chemical equivalents.

The completed equation will, therefore, be :—

$$\underset{\substack{\text{Silver}\\\text{Nitrate.}}}{Ag\ NO_3} + \underset{\substack{\text{Sodium}\\\text{Chloride.}}}{Na\ Cl} = \underset{\substack{\text{Silver}\\\text{Chloride.}}}{Ag\ Cl} + \underset{\substack{\text{Sodium}\\\text{Nitrate.}}}{Na\ NO_3}.$$

EXAMPLES FOR PRACTICE.

Complete the following:—

1. $2Ag\ (NO_3) + H_2S = ?$
2. $Pb\ (NO_3)_2 + H_2S =$
3. $H_2\ (SO_4) + Ca\ O_2\ H_2 =$
4. $KI + Ag\ NO_3 =$
5. $Fe\ Cl_2 + 2KOH =$
6. $Fe_2\ Cl_6 + 6KOH =$
7. $Ni\ (NO_3)_2 + Na_2S =$
8. $Mg\ SO_4 + 2(NH_4)\ OH =$
9. $Ba\ Cl_2 + Na_2\ SO_4 =$
10. $Bi\ Cl_3 + H_2O = Bi\ OCl + ?$
11. $Pb\ (C_2H_3O_2)_2 + H_2\ SO_4 =$
12. $Ba\ Cl_2 + (NH_4)_2\ CrO_4 =$
13. $Na_2\ CO_3 + 2HCl =$
14. $Cu\ SO_4 + 2NaOH =$
15. $Hg_2\ (NO_3)_2 + 2NaCl =$
16. $Mg\ SO_4 + H\ Na_2PO_4 + NH_4OH =$

Stochiometry.—Chemical symbols represent definite weights, or atomic weights. Chemical formulæ, therefore, enable us to calculate the percentage of any ingredient in the compounds they represent; or, from chemical equations, we may calculate the weight of any substance required by any given process, or the exact amounts evolved by it.

These calculations are all based upon the atomic weights. Molecular weights are derived from the atomic weights.

The mulecular weight of calcium carbonate, Ca CO_3, is

$(C = 12) + (O_3 = 48) + (Ca = 40) = 100$. (See Table, page 80.)

On inspection, we see that $\frac{40}{100}$ of the whole quantity is calcium, $\frac{12}{100}$ carbon, and $\frac{48}{100}$ oxygen.

Let it be desired to calculate the quantity of hydrogen in one part of water; formula H_2O.

$$(H_2 = 2) + (O = 16) = 18.$$
$$\tfrac{2}{18} = \text{Hydrogen}, \tfrac{16}{18} = \text{Oxygen}.$$

Stated in the form of a proportion, this would be $18 : 2 :: 1 : \frac{2}{18} = \frac{1}{9}$. In this proportion, the fourth term must bear the same relation to the third that the second does to the first.

What is the per cent. of calcium and oxygen in $CaCO_3$?

The first problem would be stated as follows:—

$$CaCO_3 : Ca :: 1 : x$$
$$100 : 40 :: 1 : x = \tfrac{40}{100} = .40 \text{ or } 40 \text{ per cent.}$$

In other words, calcium carbonate contains 40 per cent. of calcium. The same calculation may be made for oxygen, as follows:—

$$CaCO_3 : O_3 :: 1 : x$$
$$100 : 48 :: 1 : x = .48 \text{ or } 48 \text{ per cent.}$$

If, instead of one part, we desire the amount in ten parts, we substitute 10 for one in the third term of the equation, thus: $100 : 48 :: 10 : 4.8$ parts.

The fourth term of such an equation will always be of the same denomination as the third.

From the above, we easily deduce the following rule for the statement of such problems: **As the formula of the substance given is to the formula of the substance required, so is the weight of the substance given to x, the weight of the substance required. Reduce the formulæ to their numerical equivalents, and find the value of x.**

When three terms of an equation are given, the fourth may be found by multiplying the two **means** (second and third terms), and dividing the product by the given **extreme.**

In calculating the per cent. of any ingredient, by the above rule, the weight given is understood to be 100. Per cent. is parts per hundred.

Calculations based upon a reaction may be illustrated as follows:—

Problem.—How much sulphate of zinc can be prepared from 10 grammes of zinc?

Reaction.—$Zn + H_2SO_4 = ZnSO_4 + H_2$
Statement.—$Zn : ZnSO_4 :: 10 : x$
Numerical statement.—$65 : (65 + 32 + 64 = 161) :: 10 : x$
Solution.—$161 \times 10 = 1610$
$1610 \div 65 = 24.8$, Ans. in grammes.

Problem.—How much $NaNO_3$ will be required to make one pound of HNO_3?

Equation.—$NaNO_3 + H_2SO_4 = NaH\,SO_4 + H\,NO_3$.

The only terms of this equation concerned in the problem are $Na\,NO_3$ and HNO_3; the latter being the substance given.

Statement.—$HNO_3 : NaNO_3 :: 1 : x$ pounds.
Numerical statement.—$63 : 85 :: 1 : x$
Solution.—$1 \times 85 = 85$
$85 \div 63 = 1.35$ pounds of $Na\,NO_3$.

EXAMPLES FOR PRACTICE.

1. How much $Fe\,SO_4$ can be made from one kilogramme of iron?
2. How much mercury will be required to make one pound of calomel; (Hg_2Cl_2)?
3. Calculate the per cent. of each element in the following: KBr, KI, $HgCl_2$, Fe_2Cl_6.
4. How much silver nitrate can be obtained from 100 grammes of silver?
5. What is the volume of one kilogramme of CO_2, under standard conditions?
6. Calculate the weight of one litre of chlorine.
7. How much bismuth will be necessary to prepare one kilo. of subnitrate?
8. Calculate the percentage composition of $C_6H_{12}O_6$.
9. What quantity of sodium carbonate will be required to neutralize 5 c.c. of a 10 % HCl_2?

$$2\,HCl. + Na_2CO_3 = 2NaCl + H_2O + CO_2.$$

10. What weight and what volume of CO_2 will be given off in the above reaction?
11. Assuming that air contains 20 per cent. by volume of oxygen, what volume of air will be required to burn 1 gramme of marsh gas (CH_4)?

PART III.

INORGANIC CHEMISTRY.

Classification of the Elements.—For convenience of study, some system of classification of the elements is necessary. Many systems of classification have been proposed, but all are open to criticism; yet, we may adopt one of these with the understanding that the classification is largely an arbitrary one, and serves merely for convenience. Berzelius was the first to divide the elements into two great classes, to which he gave the names **metals** and **metalloids.** The metals are those elements which possess more or less lustre and opacity, readily conduct heat and electricity, and are **electro-positive** in combinations.

The non-metals, or metalloids, are such as are gaseous; or, if solid, have no lustre, ductility, or malleability, are poor conductors of heat and electricity, and are **electro-negative** in combinations.

This division, while it serves a general purpose, is not capable of exact application; for there are a number of the elements which are **positive** in one combination and **negative** in another. Iodine and arsenic, which most chemists regard as metalloids, have a decided lustre, and the latter forms alloys by fusion with the metals; indeed, there is no line of demarcation, between these two classes, which can be regarded as fixed.

Some classification is necessary, which is not based upon the physical properties alone, but upon their chemical properties; a classification which brings together those elements which have similar chemical properties, and similar compounds with other elements; thus enabling the student to better associate the facts of each in his mind.

There are two important chemical characters upon which most attempts at classification of the elements into groups have been based; viz.: Equivalence and electrical polarity of the atoms. By a consideration of both of these properties, the elements may be grouped so as to bring similar elements together.

The behavior of the oxides of the elements with water may be taken as an index of their polarity. Electro-negatives dissolve in water and form acids, while electro positives form bases, and some again play a neutral or double rôle.

The most successful attempt to find a natural system of classification of the elements is the one first proposed by Newlands and afterward developed by Mendelejeff, and is the only natural one in use. It is based upon the atomic weights, and is sometimes known as the **periodic law.** If a list of the elements be made, arranging them in the order of their atomic weights, from the lowest to the highest, the first seven (after hydrogen) will be found to be representative of seven groups of similar elements. (See Table, page 108.) Let each of these seven elements head a column, and arrange the rest under them in the order of their atomic weights, in lines from left to right. We notice that those elements resembling one another in their chemical properties will be found together in the vertical columns. It will be noticed that the metals are near the bottom of the table, while the non-metals are at the top. In Mendelejeff's original table there were seven vertical columns which are called the seven groups. There are twelve lateral rows which are called series, or small periods. If these lateral rows or series be numbered, it will be noticed that the members of the alternate numbered series of a given period resemble one another more nearly than the adjoining numbered ones. Thus, in the first group: Li = 7, K = 39, Rb = 85, Cs = 133, resemble one another more nearly than Na, Cu, Ag, Au. It will be noticed that hydrogen is arranged in the first period as the only one of that period. The table is imperfect in some cases, but in the main it brings together elements which form well-defined natural groups. As an example of such a group, take Nos. 2, 3, 5 and 7 of Group VII. With the increase of atomic weight they increase in specific gravity and consistency. Of the group, fluorine is strongly electro-negative, while chlorine, bromine and iodine grow more positive as the atomic weight increases. They all form acid hydrides containing one atom of basic hydrogen. They all possess a peculiar and somewhat similar pungent odor. They all have the leading equivalence of one, while the three last have a higher equivalence in certain oxygen compounds.

While there are certain striking groups brought together by this arrangement, there are some irregularities. Thus, there is no series in which hydrogen finds a place. In making this element a period by itself, the last four members of the second

SERIES.	GROUP I. $\overline{R}_2O$	GROUP II. $\overline{R}O$	GROUP III. $\overline{R}_2O_3$	GROUP IV. $R\,H_4$ $R\,O_2$	GROUP V. $R\,H_3$ R_2O_5	GROUP VI. $R\,H_2$ $R\,O_3$	GROUP VII. $R\,H$ R_2O_7.	GROUP VIII. $\overline{R}\,O_4$
1	H = 1							
2	Li = 7	Be = 9	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27	Si = 28	P = 31	S = 32	Cl = 35.5	A = 40 (?)
4	K = 39	Ca = 40	Sc = 44	Ti = 48	V = 51	Cr = 52 -	Mn = 55	Fe=56, Co=59, Ni = 59 Cu = 63
5	(Cu = 63)	Zn = 65	Ga = 70	Ge = 72	As = 75	Se = 79	Br = 80	
6	Rb = 85	Sr = 87	Yt = 89	Zr = 90	Cb. = 94	Mo = 96	= 100	Ru = 102, Rh = 104, Pd = 106, Ag=108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 120	Te = 125	I = 127	. . . .
8	Cs = 133	Ba = 137	La = 139	Ce = 140	Di = 142	Tb = 160	. .	. . . .
9	(—)	. .	E = 166	. .	. .	. .	. .	Os = 192, Ir = 193, Pt = 195, Au=197
10	. .	. .	Yb = 173	. .	Ta = 182	W = 184	. .	
11	(Au = 197)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	. .	. .	. . . .
12	. .	. .	. .	Th = 232	. .	U = 239.	. .	. . . .

period, C, N, O, and F, are made even-numbered, which removes them from the others of the same group which they most nearly resemble. Even with these imperfections, the table is an attempt to classify the elements upon some natural basis, and has enabled its author to predict the discovery of at least three new elements, viz.: gallium, scandium, and germanium, and describe their properties, years before they were discovered. This he was led to do from the vacant places in the table.

As hydrogen stands alone in the table, we shall study it first. Argon, the new element found in the atmosphere, has not been studied sufficiently to admit of classification, and is therefore introduced provisionally in Group VIII. It will be convenient to retain the classification into **metals** and **non-metals.** The non-metals will be studied first, beginning with those of the seventh group, and taking the odd-numbered series below the second. The order in which the elements will be studied is the following, with the omission of those whose symbols are in italics, as being of little interest to the medical student:—

NON-METALLIC ELEMENTS OR ODD SERIES.

		H	A			
Seventh	Group,	F.	Cl.	Br.	I.	
Sixth	"	O.	S.	*Se.*	*Te.*	
Fifth	"	N.	P.	As.	Sb.	Bi.
Fourth	"	C.	Si.	*Ge.*	Sn.*	Pb.*

METALS.

First	"	Li.	Na.	K.	Rb.	Cs.			
		Cu.	Ag.	Au.					
Second	"	*Be.*	Ca.	Sr.	Ba.				
		Mg.	Zn.	Cd.	Hg.				
Third	"	B †	*Sc.*	*Yt.*	*La.*	*Yb.*			
		Al.	*Ga.*	*In.*	*E.*	*Tl.*			
Fourth	"	*Ti.*	*Zr.*	*Ce.*	*Th.*				
Fifth	"	*V.*	*Nb.*	*Di.*	*Ta.*				
Sixth	"	Cr.	Mo.	W.	*U.*				
Seventh	"	Mn.							
Eighth	"	Fe.	Co.	Ni.	Ru.	Pd.	Os.	Ir.	Pt.

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[*] These elements, although classed in the series with non-metals, are generally regarded as metals.

[†] Non-metal.

GROUP I.

HYDROGEN.

Symbol, H. Atomic Weight, 1. Molecular Weight, 2. Density, 1. Weight of one liter = 1 crith = .0896 grm. Equivalence, one.

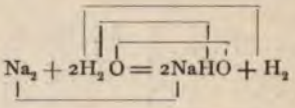
1 grain = 46.7 cu. in. at 60° F. and 30 in. barometer.
1 gram = 11.16 liters at 0° C. and 760 mm. barometric pressure.

Occurrence.—It was discovered in 1766 by Cavendish. Hydrogen occurs in a free state in the gases from volcanoes, fumeroles of Iceland and Tuscany, and in the atmosphere of the sun; in combination, it exists in water, and in most organic substances of both animal and vegetable origin. It is a necessary constituent of all acids, bases and ammoniacal compounds.

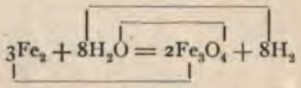
Preparation.—Hydrogen may be prepared:—

First.—By the decomposition of water, by a strong electric current, which splits the water into hydrogen and oxygen; the former appearing at the negative, and the latter at the positive pole.

Second.—By decomposing water by certain metals. When sodium or potassium is used, the decomposition takes place in the cold; but with iron and some other metals at a red heat.

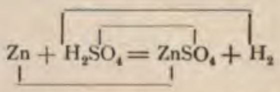


$$Na_2 + 2H_2O = 2NaHO + H_2$$



$$3Fe_2 + 8H_2O = 2Fe_3O_4 + 8H_2$$

Third.—By the decomposition of the mineral acids with some metal, as zinc, iron, or magnesium. In this case, the metal takes the place of hydrogen, which is crowded out of the acid molecule.



$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

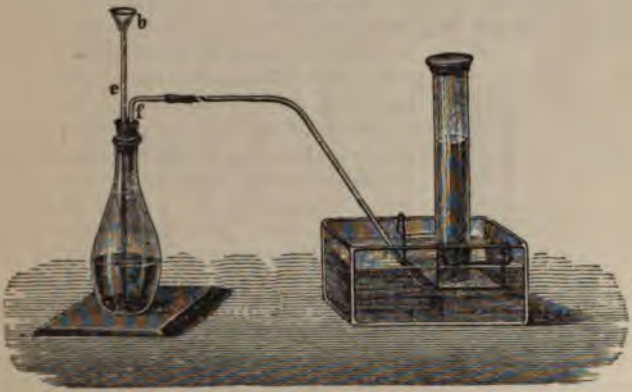
65 grams of zinc give 2 grams = 22.32 litres of hydrogen.

Water is added to dissolve the zinc sulphate formed, and to prevent it from crystallizing on the surface of the zinc. Chemically pure zinc, however, will not dissolve in very dilute acid, unless it be made one pole of a galvanic couple.

This method is the one usually employed for the preparation of hydrogen in the laboratory. The apparatus is shown in Fig. 44. The gas prepared from commercial zinc and acid is not pure, however, as it contains other gases derived from impurities in the materials used. Pure hydrogen in small quantities, may be prepared by the first method, or by decomposing water with an alloy of sodium and mercury—sodium amalgam.

Properties.—When pure, at ordinary temperatures and pressures, hydrogen is a colorless, transparent, odorless, tasteless gas. It is 14½ times lighter than air, being the lightest gas known.

FIG. 44.

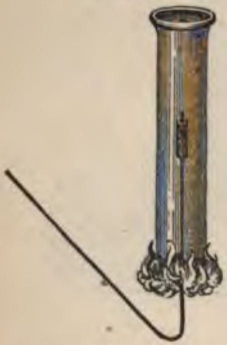


PREPARATION OF HYDROGEN.

One liter of it at 0° C. and 760 mm. pressure, weighs .0896 grm. = the crith. It is almost insoluble in alcohol, and at a temperature of —140° C. and under a pressure of 650 atmospheres, it has been condensed to a steel-blue liquid. It is the best conductor of electricity and heat among the gases. It is very diffusible, and a vessel to contain it, must be made of glass or some very compact material. Certain metals absorb large quantities of it. Palladium will absorb 900 times its volume of the gas: spongy platinum, sodium, potassium and iron also absorb considerable quantities of it. This action of the metals is called **occlusion.** During the condensation of the gas in the pores of the metal, the latter is heated to a considerable degree. A jet of hydrogen may be ignited by directing it upon a ball of finely divided platinum, or a ball of asbestos, which has been dipped into a solution of platinum chloride, and heated in the flame of a lamp.

Under ordinary conditions, hydrogen has little tendency to unite with the other elements, chlorine being the only one with which it combines directly, and then only under the influence of light. At higher temperatures it unites with oxygen, and is, therefore, readily combustible in the air, burning with a bluish and very hot flame. The product of the combustion is watery vapor, as may be shown by inverting a jar over the burning jet, and collecting the drops of water. A given weight of hydrogen produces more heat in burning than any other known combustible. It will not maintain animal respiration, but is not poisonous. A lighted candle is extinguished on being thrust into it, while the gas burns at the open mouth of the jar. On withdrawing the candle it relights. (See Fig. 45.) If hydrogen and oxygen be mixed together and a lighted taper applied to them, an explosion takes place. The hydrogen combines with one-half its volume of oxygen. In other words, when these gases combine they do so only in the one proportion. This law holds good with all chemical combinations, and is known as the **law of definite proportions.** Hydrogen has so great a tendency to unite with oxygen, at high temperatures, that it will take it from many metallic oxides, and leave the metal in the free state.

FIG. 45.



This process is called **reduction** or **deoxidation.** It is by this process that the **reduced iron** or **Ferrum Reductum** of pharmacy is produced.

Hydrogen will unite quite readily with some elements which it ordinarily does not affect, if they be put into the flask where the hydrogen is generating. Arsenic and antimony compounds, for example, are split up, and these elements unite with the hydrogen. Many oxides are reduced, and chlorine is removed from some chlorides, under these circumstances. The greater energy of the hydrogen, in these cases, is explained by the supposition that at the moment of liberation of the hydrogen atoms, and before they have combined into molecules, they are ready to take up with any atom with which they may come in contact. They are stronger in their affinities, before combining with a neighboring hydrogen atom, by just the force it will take to decompose the hydrogen molecule when once formed. This condition of an element is known as the **nascent state.** (From **nascere,** to be born). When any chemical action takes place between molecules, there is a considerable expenditure of force required to break up the combinations already formed, before new ones can be formed; and when these combinations do not exist, the new combinations take place with ease. Hydrogen is one of the constituents of the gases of the stomach and intestines, and is frequently found in the gases exhaled from the lungs. Its physiological properties, if any, are slight.

In its chemical properties, hydrogen resembles the metals more than the metalloids, usually playing the positive rôle, and forming salts in which it occupies the place of metallic atoms in similar compounds. It is easily substituted for or displaced by them. On this ground, the acids may be regarded as salts of hydrogen.

Uses.—The uses of hydrogen are limited. Owing to its lightness, it is sometimes used to fill balloons. The ascensional power, or the lifting power, of one litre of hydrogen is 1.2036 grms., and is found by deducting its weight, .0896 grm., from the weight of one litre of air, 1.2932 grammes. The lifting power of one cubic foot is about 525 grains, or one ounce and 55 grains. Hydrogen is also used with oxygen in the oxy-hydrogen blowpipe. In the laboratory, it is used as a reducing agent.

ARGON.

$A = 40$

This element was discovered in 1894 in the atmosphere by Lord Rayleigh and Prof. Ramsay. The method of separation employed by them was to pass atmospheric air through a tube containing copper turnings heated to redness, to remove oxygen, then through another tube containing magnesium heated to redness, to remove nitrogen. The residual gas was then passed over heated copper, copper oxide, and finally over heated magnesium again. This was repeated until the gas ceased to give up any more nitrogen to the magnesium, which usually required about two days. The amount of argon found in air was a little less than one per cent. Whether this is constant in air at different places, cannot be stated.

Properties.—Whether argon, as obtained by these experimenters, is an element, a modification of nitrogen, or a mixture of two or more elements, has not been definitely settled. The evidence thus far tends to show that it is an element, and not a mixture.

The element is a colorless, transparent, odorless, tasteless, inert gas, having a density of about 20.

At atmospheric pressure it liquefies at —186.9° C., to a colorless liquid having a specific gravity of 1.5. At about —190° C. it freezes to an ice-like solid. It is soluble in water to the extent of 4.05 volumes in 100 volumes at 14° C. (57.2° F.) being two-and-a-half times more soluble than nitrogen, and of about the same solubility as oxygen. Of its chemical properties nothing can be said, as all attempts thus far have failed to cause it to combine with any other substance.

The molecule is monatomic, and therefore the atomic weight is 40.

$$\text{Density} \times 2 = \text{molecular weight.}$$

There are no compounds of argon known.

NON-METALLIC ELEMENTS OF GROUP VII.

(CHLORINE GROUP, OR HALOGENS.)

	SYMBOL.	ATOMIC WEIGHT.	STATE.
Fluorine,	F.	19	gas.
Chlorine,	Cl.	35.45	gas.
Bromine,	Br.	79.95	liquid.
Iodine.	I.	126.85	solid.

The elements of this group are electro-negative, fluorine being most negative, and iodine least so. They have a characteristic, pungent odor, and act as disinfectants and bleaching agents. They enter into direct union with many of the metals to form binary compounds. They form compounds with hydrogen having well-marked acid properties. They have little affinity for oxygen, but form several oxacids and salts, all of which are rather unstable. They form the following compounds :—

HF.	—	—	—	—	—	—	—
HCl.	Cl_2O	Cl_2O_3	Cl_2O_5	HClO	$HClO_2$	$HClO_3$	$HClO_4$.
Hbr.	—	—	—	HBrO	—	$HBrO_3$	$HBrO_4$.
HI.	—	I_2O_3	I_2O_5	HIO	HIO_2	HIO_3	HIO_4.

FLUORINE.

(FLUORIN.)

F = 19.

D. = 19. Sp. Gr. 1.3. Equivalence I.

Source.—The sources of flourine compounds are native fluor spar—calcium fluoride—and cryolite—a sodium and aluminium fluoride.

Preparation.—By decomposing pure, dry hydrofluoric acid in a **U** tube composed of platinum, by means of a strong electric current from twenty or more Bunsen cells. The hydrofluoric acid must be prepared with care, and must be free from water. As hydrofluoric acid is a non-conductor, a small quantity of potassium hydrogen fluoride is dissolved in it to increase its conductivity. The apparatus is cooled to —23° C. during the process. The fluorine is liberated at the positive pole as a colorless, transparent, pungent gas, having the properties of chlorine, but much more marked. Silicon, boron, arsenic, antimony, sulphur, and iodine take fire in it. It instantly decomposes cold water, forming hydrogen fluoride (HF.), and sets free the oxygen as ozone. Most organic bodies are attacked by it, the hydrogen being removed, but the carbon remaining unattacked. It combines with hydrogen with an explosion, even in the dark. Alcohol, ether, benzene, turpentine, and petroleum take fire on being brought in contact with it. It attacks the metals slowly, in bulk, but rapidly when in powder. Owing to the action of fluorine on the metals and all glass articles, it can only be prepared in vessels of platinum or fluor spar.

Hydrogen Fluoride.—Hydrofluoric Acid (HF).—This acid is obtained by the action of sulphuric acid upon powdered fluor spar, with the aid of a gentle heat.

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

The operation is usually conducted in a lead or platinum vessel, as the acid attacks glass and most metals. The acid is a colorless, transparent gas, with a pungent odor, very irritating to the skin and mucous membranes. It is readily soluble in water, forming a colorless, highly acid and corrosive liquid, with a pungent odor. Care must be taken, in using it, not to allow it to come in contact with the skin, as it produces a painful ulcer which heals with difficulty, and also constitutional symptoms of considerable severity.

The boiling point of the liquid is between 15° and 20° C. (59 and 68° F.), and it has a specific gravity of 1.060. The most characteristic property of hydrofluoric acid is its power of dissolving glass by removing its silicon. This property is utilized for etching glass. The article to be etched is first coated with a thin layer of melted wax or paraffin, and the characters are then scratched through the wax with a steel point, so as to expose the glass where the etching is to take place. If the liquid is to be used, a wall of wax is built up around the characters and the liquid is poured into the inclosure. The characters thus etched are transparent. It is more common to invert the glass, wax downward, upon a leaden dish containing the fluor spar and sulphuric acid, and expose it to the fumes until the etching is as deep as desired. The etchings in this case are opaque, presenting the appearance of ground glass, and more easily seen. Fluorine forms no oxides.

CHLORINE.

(CHLORIN.)

$Cl = 35.5.$

D. = 35.5. Sp. Gr. = 2.47. Equivalence I, III, V or VII.

Occurrence.—Chlorine always occurs in combination in nature. The chlorides of sodium, potassium, magnesium and calcium occur in salt springs. Usual source, sodium chloride or common salt.

Preparation.—By the action of warm sulphuric acid upon sodium chloride, in the presence of manganic oxide, contained in a flask as represented in Fig. 46.

$$2H_2SO_4 + MnO_2 + 2NaCl = Na_2SO_4 + MnSO_4 + 2H_2O + Cl_2.$$

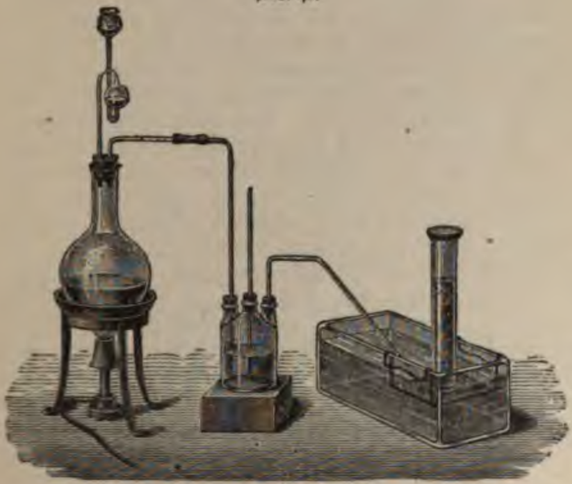
Or, by acting upon manganic oxide with hydrochloric acid.

$$4HCl + MnO_2 = MnCl_2 + 2H_2O + Cl_2.$$

For a slow continual evolution of chlorine, as for disinfecting purposes, moistened chloride of lime is exposed to the air. The calcium hypochlorite is decomposed by the carbon dioxide of the air, and chlorine is set free. For a more rapid evolution, we may use the same salt with a diluted acid. It may be collected over warm water.

Properties—Physical.—At ordinary temperatures chlorine is a greenish-yellow, pungent, suffocating gas. It is irrespirable, causing, when breathed, inflammation of the air passages. It is nearly two and a half times heavier than air; it is soluble in water, one volume of water dissolving nearly three volumes of the gas at 10° C. (50° F.). The solution, **aqua chlori**, U. S. P., is made at this temperature, and contains 0.4 per cent. by weight of the gas. It is a greenish-yellow liquid, possessing the properties of the gas, but slowly changing, in the light, into hydrochloric acid. It should bleach, but not redden litmus paper. Chlorine water should be kept in a dark place, as otherwise decomposition takes place. The Cl unites with the H of the water, forming HCl, and setting O free. Under a pressure of four atmospheres at ordinary temperatures, or a temperature of —40° C. (—40° F.), the gas is condensed to a dark yellow liquid.

FIG. 46.



Chemical Properties.—The affinities of chlorine are very strong and extensive. It is characterized by its strong tendency to combine with hydrogen and the metals, with which it forms chlorides. It combines directly with many elements, as finely divided copper, antimony or arsenic, with the evolution of light and heat. Its attraction for hydrogen is so strong that when a mixture of these gases is exposed to direct sunlight, the light of burning magnesium, or the electric light, they combine with an explosion. It burns rapidly in an atmosphere of hydrogen, forming gaseous hydrochloric acid, HCl. It is capable of existing in two **allotropic** states; the one active and the other passive. The passive or inactive form is the one obtained when the gas is prepared in the dark. When prepared in daylight it is very active in its properties. When an element is capable of existing in two or more forms, having different properties, these forms are called **allotropic** conditions; the property is called **allotropism**.

One of the most marked chemical properties of chlorine is its affinity for hydrogen. So great is this affinity, that many organic compounds are spontaneously decomposed by it; the chlorine combining with the hydrogen of the compound and setting the carbon free. A paper wet with turpentine and plunged into a jar of chlorine, takes fire and deposits the carbon as a dense black cloud, while fumes of HCl fill the jar. The well-known bleaching and disinfecting powers of chlorine are due to its affinity for hydrogen. Most vegetable colors, when moist, are readily discharged by chlorine. The chlorine combines with the hydrogen of the water and sets free the oxygen, which, in the nascent condition, is a powerful oxidizer, and decomposes the coloring agent, or organized germ, as the case may be. In some cases the chlorine acts directly upon the organic matters, uniting with a portion of their hydrogen to form HCl, and a portion of it entering the molecule to take the place of the hydrogen removed. Thus, with marsh gas, hydrochloric acid and methyl chloride are produced. $CH_4 + Cl_2 = CH_3Cl + HCl$.

Hydrogen Chloride.—Hydrochloric Acid.—Acidum Muriaticum.—Acidum Hydrochloricum, U. S. P.—(HCl). Hydrochloric acid occurs very sparingly in nature. It is found in volcanic gases and in the gastric juice of mammals.

Preparation.—The acid is usually prepared from sodium chloride or common salt, by treatment with commercial sulphuric acid, with the aid of a gentle heat.

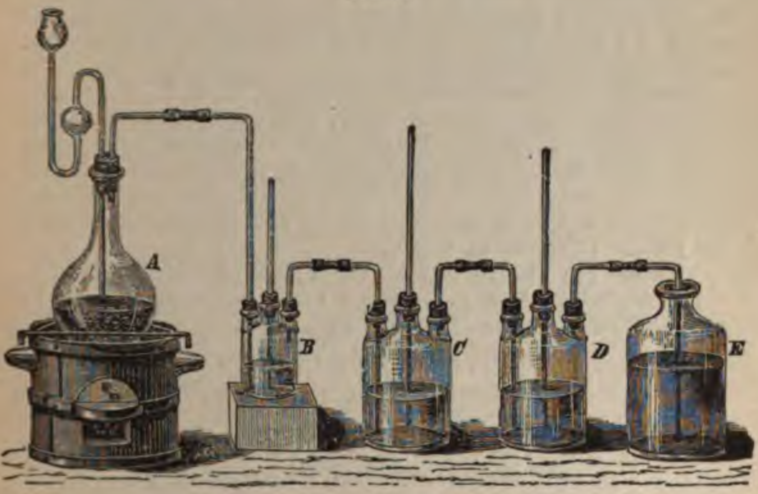
The process is sometimes conducted as a special process, but a large quantity of the acid is prepared, as a side product, in the preparation of sodium carbonate by Leblanc's process. The first step in this process is to treat the salt with sulphuric acid, and thus convert it into sodium sulphate. The acid set free by this process is collected and sold as impure hydrochloric acid.

$$H_2SO_4 + 2NaCl = 2HCl + Na_2SO_4.$$

The acid may be prepared in small quantity by the direct union of equal volumes of chlorine and hydrogen, under the influence of sunlight or the electric spark.

Properties.—Hydrochloric acid is a colorless, transparent gas, having a pungent, penetrating odor, a sharp, sour taste, an acid reaction, and produces great irritation of any tissue with which it comes in contact. It is irrespirable and extinguishes a flame. It is very soluble in water. One volume of this liquid dissolves 450 volumes of the gas at 15° C. (59° F.). This solution forms the ordinary **muriatic acid.** The specific gravity of the solution is 1.21, and contains about 32 per cent. of HCl. The sp. gr. of the gas (air = 1) is 1.264; the density (hydrogen = 1) is 18.25. Under a pressure of 40 atmospheres, at 10° C. (50° F.), it condenses into a colorless, limpid liquid, having a sp. gr. of 1.27. A strong solution in water fumes strongly in the air, giving off a part of the gas. On being heated it gives off its acid rapidly. The commercial muriatic acid is yellow in color, due to the presence of ferric chloride. It also contains other impurities, and is used only for manufacturing purposes.

FIG. 47.



PREPARATION OF HCl.

The composition of the acid may be determined by means of the apparatus shown in Fig. 50, p. 132. The apparatus is filled with the strongest commercial acid mixed with ten volumes of a saturated solution of common salt (NaCl). The binding posts are connected with a battery of two Bunsen cups. The chlorine separates at the positive pole, and the hydrogen at the negative pole. The volumes of the two gases are equal. By the use of the apparatus shown in Fig. 51, we may arrive at the same result by synthesis. We introduce, through the stopcock at the top of the apparatus, equal volumes of hydrogen and chlorine. By opening the stopcock below, we draw off the mercury until the height of the column is the same in both limbs. We connect the wires to a battery and induction coil arranged as in Fig. 34. On passing the current, a series of sparks is sent through the mixed gases, causing them to combine with an explosion. No contraction is observed. No excess of either gas is left, but a new gas has taken their place, viz.: hydrochloric acid. (See page 83.)

Acidum Hydrochloricum, U. S. P., a colorless, fuming liquid, having a pungent odor and an intensely acid taste. Its sp. gr. is 1.163 at 15° C. (59° F.), and it contains 31.9 per cent. of absolute hydrochloric acid.

Acidum Hydrochloricum Dilutum, U. S. P., is made by diluting the stronger acid with water. (Strong acid 100 parts, distilled water 219 parts.) The sp. gr. = 1.050, and contains 10 per cent. of HCl. Pure hydrochloric acid should be colorless, and when diluted with distilled water, should give no precipitate with H_2S, NH_4OH in excess, or $BaCl_2$, and should not dissolve gold leaf. (Absence of HNO_3.)

Tests.—(1) Heated with MnO_2, it gives off Chlorine.

(2) Added to $AgNO_3$, it gives a curdy, white ppt. soluble in ammonia water, but insoluble in nitric acid.

$$AgNO_3 + HCl = AgCl + HNO_3.$$

(3) Added to mercurous nitrate, it gives a white ppt. which is blackened by ammonia water.

$$Hg_2(NO_3)_2 + 2HCl = Hg_2Cl_2 + 2HNO_3.$$
$$Hg_2Cl_2 + 2NH_4OH = NH_2Hg_2Cl + NH_4Cl + 2H_2O.$$

Nitro-Muriatic Acid, Acidum Nitrohydrochloricum, U. S. P. (Aqua Regia). This is made by mixing 180 c.c. of nitric acid with 820 c.c. of hydrochloric acid, in a capacious glass vessel, and when effervescence has ceased, pouring the product into amber-colored glass-stoppered bottles.

The two acids act chemically upon each other, forming chloronitric or chloronitrous gas and chlorine. These equations express the reaction that probably occurs.

$$HNO_3 + 3HCl = NOCl_2? + 2H_2O + Cl.$$
$$HNO_3 + 3HCl = NOCl + 2H_2O + Cl_2.$$

This acid has the power of dissolving gold, "the king" of metals, and hence its name aqua regia. It is a golden yellow, fuming, and very corrosive acid, smelling strongly of chlorine.

Acidum Nitrohydrochloricum Dilutum, U. S. P., is made by mixing 40 c.c. of nitric acid with 180 c.c. of hydrochloric acid, and when effervescence has ceased, adding 780 c.c. of distilled water.

BROMINE—BROMUM, U. S. P.

BROMIN.

$Br = 80.$

Specific Gravity 2.99 at 15° C. (59° F.). Density of Vapor 80.

History and Occurrence.—Discovered by Balard, in sea-salt, in 1826. It never occurs native, but is found combined with the alkaline metals and magnesium in sea-water, certain salt springs, and the ashes of sea-weeds.

Preparation.—Sea-water or brine, which contains chlorides, bromides, and iodides of K, Na, Ca and Mg, is evaporated down, so that some of the constituent salts are separated by crystallization.

The evaporation takes place first in large iron pans, and, after allowing the salts to settle, the liquor is further evaporated in a series of wooden tanks, five in number, which are heated by steam pipes; these tanks are placed at different elevations, one above the other. The liquor remains one day in each tank, and when it reaches the lowest, or fifth tank, it contains only a few of the more soluble salts, chiefly bromide of magnesium. The crystals are removed from each tank before the liquor is drawn off.

The last mother liquor is called bittern. The bittern is treated with chlorine gas, which liberates bromine.

$$MgBr_2 + Cl_2 = MgCl_2 + Br_2.$$

It is then shaken up with ether, which dissolves the bromine and rises with it to the surface. Then it is separated with pipettes, mixed with potassium hydroxide, and evaporated to dryness, leaving potassium bromide and bromate.

$$3Br_2 + 6KOH = 5KBr + KBrO_3 + 3H_2O.$$
$$5KBr + KBrO_3 + \text{heat} = 6KBr + 3O.$$

The potassium bromide is then treated with manganese dioxide and sulphuric acid, which liberates the bromine in a pure state.

$$2KBr + MnO_2 + 2H_2SO_4 = K_2SO_4 + MnSO_4 + 2H_2O + Br_2.$$

Properties.—Bromine is a heavy, dark-red, mobile liquid, evolving, even at ordinary temperatures, a yellowish-red vapor, highly irritating to the eyes and lungs, and having a peculiar, pungent, suffocating odor like that of chlorine.

It is soluble in thirty parts of water, readily soluble in alcohol, ether, carbon disulphide and chloroform, imparting its color to the solutions.

It is completely volatilized on exposure to air or to heat. It destroys the color of litmus and indigo, and colors starch solution yellow.

Chemical Properties.—The chemical properties of bromine are similar to those of chlorine, but somewhat feebler. Bromine is poisonous. It may be recognized by its color, odor, or by the yellow or brown color of its solution in chloroform. It gives a yellow or orange color with starch paste. A solution of argentic nitrate precipitates it from its solutions, as a yellowish-white powder, which is soluble with difficulty in ammonium hydroxide.

Hydrogen Bromide.—Hydrobromic Acid (HBr). This acid may be prepared by treating phosphorus, immersed in cold water, with bromine, and distilling the resulting liquid. The bromine combines with the phosphorus, forming PBr_5, which is decomposed by the water into phosphoric and hydrobromic acids.

$$PBr_5 + 4H_2O = H_3PO_4 + 5HBr$$

It may also be prepared by the action of dilute sulphuric acid (7 parts acid to one of water), upon a hot solution of potassium bromide. (Squibb.)

$$2KBr + H_2SO_4 = 2HBr + K_2SO_4$$

Another method is to pass sulphuretted hydrogen through an aqueous solution of bromine.

$$Br_2 + H_2S = 2HBr + S$$

Or by double decomposition between potassium bromide and tartaric acid.

$$KBr + H_2C_4H_4O_6 = HBr + KHC_4H_4O_6$$

Bitartrate of potassium precipitates and leaves HBr in solution. The disadvantage of this method is that some of the bitartrate remains in solution. Diluted Hydrobromic Acid is official. It contains 10 per cent. of absolute hydrobromic acid. It is a clear, colorless liquid, having properties closely resembling those of hydrochloric acid. Its sp. gr. is 1.077 at 15° C. (59°F.).

The acids and salts of bromine, are analogous to the corresponding acids and salts of chlorine.

Hydrobromic is a monobasic acid, and forms compounds called bromides.

Tests for Bromides.—1. With silver nitrate, a yellowish-white ppt. of silver bromide is produced, which is insoluble in nitric acid, and sparingly soluble in ammonia water.

2. Treated with chlorine water, the bromine is liberated, and may be dissolved by shaking with chloroform, ether or carbon disulphide.

IODINE.—IODUM, U. S. P.

IODIN.

I=127.

Specific Gravity 4.948.

History and Occurrence.—Iodine was discovered by Courtois in the ashes of sea-weeds in 1812. It occurs in certain mineral springs with chlorine and bromine, but in less quantities. It is obtained mostly from the ashes of certain sea-weeds collected on the shores of Scotland and France.

Preparation.—The sea-weed is first dried in the sun, and then burned in shallow excavations, at a low heat, so as not to volatilize the iodine. The ash (called "kelp") is then leached with water, which dissolves out the salts, and the solution is evaporated in open pans, so as to separate the other crystallizable salts. The mother liquor, called "iodine ley," which still contains some sodium carbonate, hyposulphite and sulphide, is mixed with ⅛ of its bulk of sulphuric acid and allowed to stand 24 hours.

Decomposition of the above-named salts takes place, with the evolution of CO_2, SO_2 and H_2S. The liquid, which contains iodine as sodium iodide, is then put into a retort, and treated with manganese dioxide and some more sulphuric acid, and heated. The iodine now distils over and is condensed in suitable condensers.

$$2NaI + 2H_2SO_4 + MnO_2 = Na_2SO_4 + MnSO_4 + 2H_2O + I_2.$$

Iodine is a bluish-black crystalline solid, occurring in bright scales or tablets, which emit even at ordinary temperatures a very irritating, pungent vapor. When heated, it melts at 114° C.

(237.2° F.), and is gradually dissipated in the form of a beautiful violet-colored vapor, of the density of 126.53.

Medical Uses.—It is used externally as a counter-irritant and discutient; internally, as an antizymotic and alterative. In large doses, it acts as an irritant poison. It is eliminated by the kidneys, saliva and faucial mucous membrane, but not by the skin. In administering it, silver spoons should be avoided, as it attacks silver.

The following three preparations of free iodine are official: **Tinctura Iodi,** a solution in alcohol (70 gms. to 1000 c. c.). When freshly made it is precipitated from this solution with water, but after some time it undergoes changes which prevent this. The so-called **colorless tincture** is made by adding ammonium hydroxide to the above tincture, in sufficient quantity to decolorize it by converting the iodine into ammonium iodide.

Liquor Iodi Compositus (Lugol's solution), is a solution of iodine and potassium iodide in water. Iodine 5 gms, KI, 10 gms. Distilled water q. s. to make 100 gms. **Unguentum Iodi** contains 4 per cent, of iodine, rubbed up with potassium iodide and water and mixed with lard.

Hydric Iodide, or Hydriodic Acid (HI).—A solution of this acid is prepared by passing hydric sulphide through water containing iodine in suspension, until the iodine disappears, and then filtering from the precipitated sulphur.

$$I_2 + H_2S = 2HI + S.$$

The acid, when pure is a colorless gas, fuming in the air, having a penetrating odor resembling in most of its properties those of hydrochloric acid, although less stable and less active. Solutions of hydriodic acid are very prone to decomposition, with liberation of free iodine. Syrupus Acidi Hydriocidi is official; it is made by mixing an aqueous solution of potassium iodide with an alcoholic solution of tartaric acid. The mixture is cooled by ice water, the precipitate separated by filtering, and syrup added. This syrup contains about 1 per cent. by weight of absolute hydriodic acid.

The reaction which takes place in the above process is thus expressed:

$$KI + H_2C_4H_4O_6 = KHC_4H_4O_6 + HI.$$

The iodides of potassium, sodium, iron, lead, mercury, arsenic, ammonium, and sulphur are used in medicine. The following compounds are also known: ICl, ICl_3, ICl_5, IBr, IFl_5, and NI_3. The last is a very explosive compound.

Tests for Iodine and Iodides.—1. Free iodine turns gelatinized starch blue.

2. To a solution containing free iodine, add a few drops of carbon disulphide and shake. The carbon disulphide will fall to the bottom of the vessel in the form of a bead of a beautiful violet color. Chloroform may be used instead of the carbon disulphide.

3. To a solution of an iodide add a little chlorine water, and test for free iodine, as above.

4. To a solution of an iodide add nitrate of silver solution; a pale yellow precipitate will form, which is insoluble in nitric acid and in ammonia water.

5. Acetate of lead gives a yellow precipitate of lead iodide.

GROUP VI.—NON-METALLIC MEMBERS.

Oxygen, O = 16
Sulphur, S = 32
Selenium, Se = 79
Tellurium, Te = 125

The elements of this group are dyad, tetrad, or hexad, with the exception of oxygen, which is always dyad. They all combine with hydrogen in the proportion of RH_2. With the exception of H_2O their hydrides have acid properties. Oxygen is the most electro-negative and tellurium the least so.

OXYGEN.

Symbol, O. Atomic Weight, 16 (15.96). Molecular Weight, 32. Weight of 1 liter, 1.43 grams. 16 grams = 11.16 liters under standard temperature and pressure.

Occurrence.—Oxygen was discovered by Priestly, in England, in 1774, and at the same time by Scheele in Sweden, independently of each other. It exists in the air in the free or uncombined state, mixed with nitrogen and small quantities of other gases. It enters into the composition of a great variety of compound bodies, such as minerals, vegetable and animal bodies. Water is eight-ninths, sand one-half, and alumina one-third oxygen, by weight.

Preparation.—Oxygen may be prepared:—

First.—By heating mercuric oxide in a retort or flask, when it breaks up into oxygen and black mercurous oxide; or, if the temperature be high, into oxygen and metallic mercury.

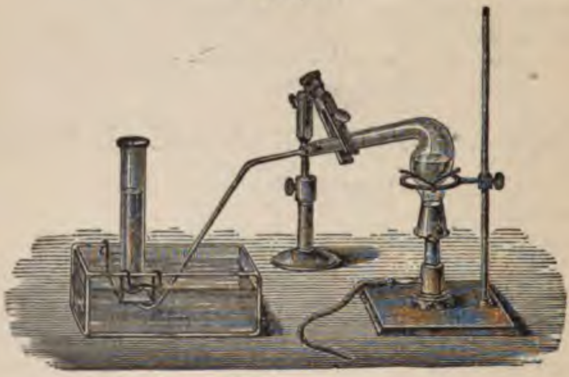
$$2HgO = 2Hg + O_2.$$

Second.—By heating black manganic oxide (MnO_2) to redness, in an iron or clay retort, when it gives off a part of its oxygen.

$$3MnO_2 = Mn_3O_4 + O_2.$$

Third.—By decomposing acidulated water with a current of electricity. The oxygen obtained in this way is very pure, but the method is too slow for ordinary use.

FIG. 48.



Fourth.—A good method, and the one most often employed, is by heating potassium chlorate.

$$2KClO_3 = 2KCl + 3O_2.$$

The evolution of the gas takes place more regularly and at a lower temperature, if the chlorate be mixed with ferric oxide, cupric oxide, or manganic dioxide. In practice, the last is generally used in the proportion of one part of the oxide to two or three parts by weight of the chlorate. The manner in which the oxide acts is somewhat obscure, for it seems to undergo no change in composition, and is found to be unaltered in the residue left in the retort.

The process may be conducted in a round-bottom glass flask, furnished with a large-size delivery tube, provided that the heat be carefully regulated and not allowed to become too high. The gas is collected in an inverted jar in a pneumatic trough. See Fig. 48.

One kilogramme of the chlorate ought to yield about 140 liters or 5 cu. ft. of oxygen.

Properties.—Oxygen, when pure, is, at ordinary temperatures, a colorless, transparent, odorless, tasteless gas, slightly heavier than air. Its sp. gr. is 1.10563. Water dissolves three per cent. of its volume, at ordinary temperatures. Under a pressure of 300 atmospheres, and at a temperature of—140° C., it condenses to a transparent liquid whose specific gravity is 0.9787 (Pictet).

Liquid oxygen boils at —180° C. (—299° F.) under atmospheric pressure, and its absolute boiling point, above which it cannot be condensed to a liquid, and known as the **critical temperature,** is —113° C. (—203° F.). Every gas seems to have a critical temperature peculiar to itself Oxygen is magnetic. The magnetism of the atmospheric oxygen is equal to that of a layer of iron covering the surface of the earth 0.1 milimeter in thickness.

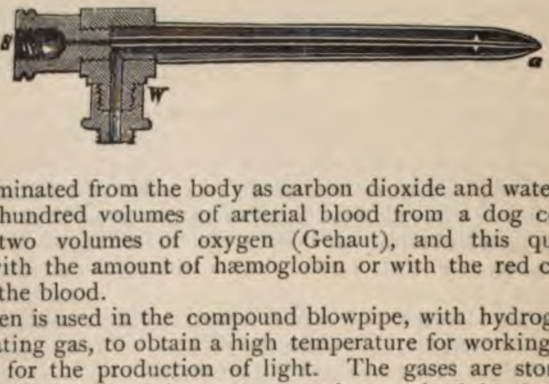
Oxygen forms oxides of all the known elements except bromide and fluorine. Its range of affinities, and its energy of combining power are its characteristic chemical properties. Most elements combine directly with it, especially at high temperatures. When this oxidation is accompanied by light and heat it is called **combustion.** A body is said to be combustible when it unites readily with oxygen, and emits light and heat in so doing. A combustible body usually requires to be heated to a more or less elevated temperature before it will be acted upon by atmospheric oxygen ; but when the process has once begun, it is kept up by the heat generated in burning.

Some bodies, not usually regarded as combustible, will burn when heated to a red heat and plunged into an atmosphere of pure oxygen ; for example, a steel watch spring or small iron wire, so treated, will burn with great brilliancy. Bodies which burn in air with difficulty, burn in pure oxygen with great readiness. Oxygen is the great supporter of combustion, but the action of oxygen and the combustible body are mutual. A jet of air may be burned in a jar of illuminating gas or hydrogen as readily as these last burn in the air. Oxidation often takes place slowly, and the heat produced, although the same in both cases, passes off into the air or surrounding bodies, so that the temperature does not rise much above that of the air. This is sometimes termed **slow combustion**; or, more commonly, oxidation.

Most ordinary combustibles contain carbon and hydrogen, and in such cases the results of the process are carbon dioxide and watery vapor. In case the combustible contains sulphur, it becomes sulphurous oxide; if nitrogen, it becomes either free nitrogen or ammonia, according as the oxidation is complete or incomplete. The respiration of animals is similar in effect to combustion.

Uses.—The uses of oxygen are numerous. The oxygen taken into the air vesicles of the lungs passes through their thin walls, by diffusion, into the blood. There it combines with the hæmoglobin and circulates with it throughout the body, assisting in burning up the waste products of the broken-down tissues. It is eliminated from the body as carbon dioxide and water.

FIG. 49.



One hundred volumes of arterial blood from a dog contain twenty-two volumes of oxygen (Gehaut), and this quantity varies with the amount of hæmoglobin or with the red corpuscles of the blood.

Oxygen is used in the compound blowpipe, with hydrogen or illuminating gas, to obtain a high temperature for working platinum or for the production of light. The gases are stored in separate receptacles under pressure, and are mixed in the blowpipe immediately before burning.

The construction of the blowpipe is shown in section by Fig. 49.

For the production of light, the flame is projected upon a small cylinder cut from unslaked lime. The flame heats the lime to a brilliant white heat which gives an intense light.

In the ordinury projecting lantern, the light from the heated lime is thrown through a lens upon a screen. Objects or transparencies placed in the light before the lens are then observed upon the screen. Oxygen, either pure or mixed with nitrogen or nitrous oxide, and condensed into cylinders, has been used with some success in the treatment of various long affections. When taken in this way, it acts as a tonic and stimulant, by oxidizing the blood; and, by forcibly inflating the lungs, it increases by several cubic inches the air capacity.

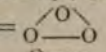
In the air, the oxygen is mixed with nitrogen to dilute it and to moderate its action. Oxygen is of use as a supporter of combustion, to afford us artificial heat and light. With this heat we drive our steam engines, warm our houses, smelt our ores and cook our food.

Ozone.—If a series of electric sparks be passed, for a few minutes, through a portion of air or oxygen gas confined in a tube, it acquires a peculiar pungent odor, exhibits properties which it did not previously possess, and undergoes a contraction in volume. The same odor is usually detected in the air in the neighborhood of a frictional electrical machine while in operation; or in the gas given off by a mixture of potassium permanganate and sulphuric acid.

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + O_2 + O_3.$$

$O_2 = O{=}O$

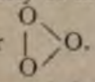
Oxygen.

$O_3 =$ 

Ozone.

or, when phosphorus, partially covered with water, is exposed to the air and allowed to undergo slow oxidation; or by the electrolysis of water containing sulphuric and chromic acids. Ozone can often be detected about a galvanic battery, using as the exciting fluid a solution of sulphuric acid and potassium dichromate.

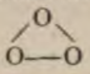
Ozone has been prepared in the pure state by passing ozonized oxygen through a tube cooled by liquid oxygen to —184° C. (—299° F.). Thus prepared, it is a steel-blue liquid boiling at —106° C., and evaporating into a blue gas.

The density of the gas is 24, and its molecular weight is therefore 48, or 

The ozone of the air never exceeds one part in 700,000. It is most abundant in May and June, and least in December and January.

Properties.—The properties of ozone are those of oxygen, intensified. It is a very powerful oxidizing agent, tarnishes silver and mercury, sets iodine free from potassium iodide, and is rapidly destroyed by contact with easily oxidizable organic matters, and by a temperature of 149° C. (300° F.). In this last case, it is reconverted into oxygen. It is a strong bleaching agent. It is soluble in oil of turpentine and in ether.

In preparing ozone from oxygen, a contraction takes place, and it again expands on being reconverted into ordinary oxygen. This shows that it is a condensed form of oxygen.

Ozone is 1½ times heavier than oxygen, and its molecule is represented by  or O_3.

Tests.—The presence of ozone may be detected by its action upon a paper saturated with a solution of potassium iodide and boiled starch paste. This paper becomes blue by its action, owing to the liberation of iodine, which gives a blue color with starch. A piece of reddened litmus paper saturated with potass. iodide also becomes blue. A paper moistened with an alcoholic solution of guaiacum is also changed to a light blue by its action. A piece of paper impregnated with a solution of manganous sulphate or lead hydrate turns dark brown or black in its presence. These reactions disappear when the air is heated to 260° C. (500° F.). Ozone is found in the air, especially after thunder storms, and when in appreciable quantities, acts as a purifier of the air, destroying, by its oxidizing action, many forms of organized germs hurtful to animal and vegetable life. On this account, it has been regarded as a valuable antiseptic and disinfectant. As it is very irritating to the mucous membranes, and when present to any considerable extent causes distressing coryza, or even hæmoptysis, it is to be recommended with caution.

HYDROGEN AND OXYGEN.

Two compounds of these elements are known.

Hydrogen oxide, or water, H_2O.
Hydrogen peroxide, or oxygenated water, H_2O_2.

HYDROGEN OXIDE, OR WATER.

Occurrence.—Water is so widely distributed in nature, that it is almost universal. It exists in the three states; solid, liquid, and gas or vapor.

It occurs in the solid form below the temperature of 0° C. (32° F.), and as a liquid between 0° C. (32° F.) and 100° C. (212° F.), and as a vapor above 100° C. (212 F.). In the form of vapor it exists in the air at ordinary temperatures. It is poured into it from combustion in various manufacturing processes, from volcanoes, by spontaneous evaporation from the surface of the ground, bodies of water and the leaves of plants. Seven-eighths of the entire human body is water. Potatoes contain 75 per cent.; watermelons, 94 per cent.; and cucumbers, 97 per cent. It enters into the composition of many rocks, and forms a necessary part of many crystals, where it is known as water of crystallization.

Composition.—The composition of water may be determined in two ways: by analysis and by synthesis. If a current of electricity be conducted through a vessel of water, slightly acidulated with sulphuric acid, the water will be decomposed into two gases, hydrogen and oxygen, in the proportion of two volumes of the first to one of the second. If, now, these gases be mixed together in the same proportion, and an electric spark sent through the mixture, they recombine with an explosion. If **equal volumes** of the two gases be used, there will remain, after the explosion, one-fourth as much gas as was taken, which, on testing, will be found to be oxygen.

These two experiments show that the proportion of the gases, by volume, must be two of hydrogen to one of oxygen. On weighing the two gases, we find that the oxygen weighs eight times as much as the hydrogen, *i. e.*, by weight, water is composed of $\frac{8}{9}$ oxygen and $\frac{1}{9}$ hydrogen.

The recombination is effected in the eudiometer of the construction represented by Fig. 51 and the decomposition in the apparatus shown in Fig. 50. For the synthesis of water, the mixed gases are introduced into the graduated limb (Fig. 51) through the stop-cock at the top. The wires from a small induction coil are connected with the two platinum wires soldered into the glass just below the stop-cock, and which are separated within the tube by a space about $\frac{1}{16}$ of an inch. On connecting the coil with the wires from the battery, a spark is sent across the space between the platinum wires, which ignites the gases. In Fig. 50 the wires are seen to pass through the tubes at the bottom and terminate in two strips of platinum foil, from which the gases escape to the top of their respective limbs. If the graduated limb in Fig. 51, containing the gases to be combined, be surrounded by a larger tube, through which steam from a kettle is kept passing, and the gases are measured before and after the explosion, at the same temperature, it will be found that the steam produced by the combination of the oxygen and hydrogen, will occupy two-thirds of the volume of the mixed gases before the explosion. (Page 83.) That is, the two volumes of hydrogen and the one volume of oxygen have formed two volumes of steam or vapor of water. Applying the law of Avogadro, it will be seen that there are the same number of molecules of water produced as there were molecules of hydrogen taken. Now, as we have seen (page 83) that the hydrogen molecule contains two atoms, the molecule of water must contain two atoms of hydrogen. By the same reasoning, it may be shown that the molecule contains but one atom of oxygen; or, the formula is H_2O.

FIG. 50.

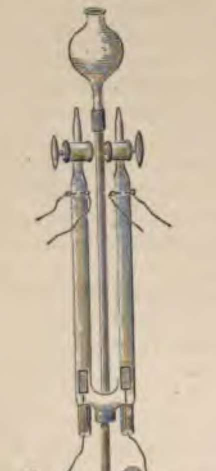
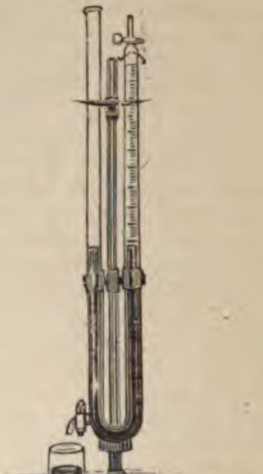


FIG. 51.



Preparation.—Water may be prepared in several ways by chemical means.

First.—The simplest method is the direct union of the gases.

$$2H_2 + O_2 = 2H_2O.$$

Second.—It is always produced by burning in the air hydrogen gas, or any combustible containing it, and may be condensed by conducting the products of the combustion through a tube or flue kept cool by immersing it in cold water.

$$\underset{\text{Marsh. Gas.}}{CH_4} + \underset{\text{Oxygen.}}{2O_2} = \underset{\text{Carbon. Dioxide.}}{CO_2} + \underset{\text{Water.}}{2H_2O.}$$

Third.—As one of the products of the action of an acid upon a base, or a metallic oxide. Thus:—

$$\underset{\text{Potass. Hydroxide.}}{K{-}O{-}H} + \underset{\text{Hydric. Nitrate.}}{HNO_3} = \underset{\text{Potass. Nitrate.}}{KNO_3} + \underset{\text{Water.}}{H_2O.}$$

Fourth.—The reduction of a metallic oxide by hydrogen or some organic substance containing it.

$$C_2H_6O + 6CuO \text{ at red heat} = 3Cu_2 + 2CO_2 + 3H_2O$$
$$2CuO + 2H_2 = Cu_2 + 2H_2O.$$

Properties—Physical.—When pure, water is a colorless, transparent, mobile liquid, without taste or odor. When viewed in large quantity, however, it has a bluish color. It is a poor conductor of heat and electricity. When water is cooled below 0° C. (32° F.) it assumes the solid state, called ice. When the temperature is raised to 100° C. [212° F.) in ordinary conditions, it assumes the gaseous state, called steam. This point is called the boiling point. The boiling point is higher than 100° C. under an increased pressure Solid matter in solution raises the boiling point and lowers the freezing point. Water at a temperature of 4° C. (39.2° F.) is taken as the unit of specific gravity of liquids and solids. At this temperature it possesses its greatest density. When it is heated above or cooled below this point, it expands and becomes less dense. Water is 773 times heavier than air at 0° C., and 11,147 times heavier than hydrogen. Water expands quite rapidly and with great force on solidifying, and hence ice is lighter than water. This expansion is supposed to be due to the greater space required for the molecules in arranging themselves into crystals. The form of the crystal of water is hexagonal. This may frequently be seen in small snow-flakes received upon a dark surface; the lines of the three equal axes can often be seen with great distinctness.

The variations in the boiling point of water are much greater than those of the freezing point, but the latter is subject to slight variations of temperature Water may be cooled in capillary tubes to —15° C. (5° F.) before it solidifies, if the tubes remain at rest; but if they are agitated, when at this low temperature, the water will instantly solidify. The agitation favors the movement of the molecules into the position to form crystals, and hence large bodies of water freeze at a higher temperature when agitated by a gentle breeze than when the air is very calm. Although converted into vapor most rapidly at 100° C., water (even ice and snow) undergoes evaporation at all temperatures, especially when the air is dry. Owing to its great solvent power for solids, pure water is never met with in nature. There are comparatively few substances which are totally insoluble in water. When we wish to prepare pure water, we generally resort to the process of distillation, rejecting the first 20 per cent. of that which distils over, and also the last 20 per cent. It is by no means an easy matter to prepare absolutely pure water, even by this process; but, by conducting the process carefully with the above precautions, we may obtain a water pure enough for all ordinary chemical purposes. Pure water is generally selected as the solvent of chemical substances which are to be submitted to any chemical change, because the reactions take place more readily in solution than when in the solid state, and because water is a neutral body, which does not complicate the result by taking part in the action itself. The vapor of water is transparent, invisible and colorless. Its density is 9, and its sp. gr., referred to air, is 0.6234. One volume of water will produce 1696 volumes of steam, or, approximately, one cubic inch of water will produce one cubic foot of steam at 100° C. (212° F.), and will absorb 536.0 units of heat.

Chemical properties.—We have already referred, in speaking of the preparation of water, to some of its chemical properties. It unites directly with many metallic oxides to form bases or hydroxides, and with some oxides of the metalloids to form acids.

$$CaO + H_2O = CaO_2H_2 = \text{base.}$$
$$SO_3 + H_2O = H_2SO_4 = \text{acid.}$$
$$CO_2 + H_2O = H_2CO_3 = \text{acid.}$$

It enters into a feeble union with most metallic salts in solution, and separates with them when they crystallize, as water of crystallization. Certain substances exhibit a marked tendency to combine with water, or to absorb it from the air, and are used in the laboratory as drying agents. Among these are **calcium chloride, sulphuric acid** and **phosphoric pentoxide.**

Natural Waters.—As already stated, natural waters are never free from dissolved impurities. They contain gaseous, liquid and solid impurities, varying according to the source whence these are derived, the temperature, the nature of the soil or rocks over which they have flowed or the state of the air at the time. Natural waters may be divided into **potable** (or drinkable), **mineral,** and **saline** waters.

Potable Waters.—To this class belong well water, spring water, river water, lake water and ice water.

The purest natural waters are **rain** and **snow water** from mountainous and country districts. The purity of rain water varies with the locality where it falls. In the neighborhood of large cities, where the air is charged with the products of large factories, etc., it will contain whatever of these can be washed out of the air.

Sulphuric acid, for example, is comparatively abundant in the air of large cities. The rain water of London, as given by Dr. R. Angus Smith, contains 20.5 parts per million, while that of inland places in England contains only 5.5 parts; and that from inland places in Scotland, only 2 parts, while from Glasgow it contained 70 parts.

The source of the sulphuric acid is mostly the combustion of coal containing sulphur. The chlorides in rain water, principally **sodium chloride,** vary with the distance from the sea coast.

Ammonium salts, nitrates and nitrites are found in small quantities, derived from decomposing organic matter and from the combustion of coal. Another source of these compounds, is the oxidation of a small quantity of the nitrogen of the air by ozone generated by lightning. Rain water also contains more or less dust and organic matter, which it washes out of the air in falling. The gases found in rain water are carbon dioxide (CO_2), nitrogen, oxygen, and sometimes in cities, sulphur dioxide (SO_2), and hydrogen sulphide (H_2S).

$$\text{Peligot's analyses show } \left.\begin{array}{ll} CO_2 & 2.4 \\ \text{Oxygen} & 6.59 \\ \text{Nitrogen} & 14. \end{array}\right\} \text{c.c. per liter.}$$

It will be noticed that the proportion of oxygen in the air of rain water is about twice as great as that of the atmosphere.

Rain water, as ordinarily collected on roofs of houses, is very much contaminated with both organic and mineral matter washed from the roof on which it falls. It is very liable to become putrid from the decomposition of this organic matter, and to breed the larvæ of certain insects. Melted snow furnishes a water even purer than rain water, especially if we collect that which falls toward the end of a storm.

Ice water varies very much in purity, according to the purity of the water from which the ice is obtained. Ice is always purer than the water from which it is formed, and when obtained from clear lakes or rivers it is often the purest of natural waters, owing to the fact that in the crystallization of water, or freezing, it leaves part of the dissolved solids and gases in the remaining water. The absence of the usual gases, however, renders ice water **flat** to the taste.

Spring and Well waters are simply rain water which has been filtered through a more or less thick layer of soil. The nature and quantity of the dissolved matters will depend upon the nature of the soil and rock through which it percolates or over which it flows.

In large cities, where the soil is saturated with filth, the well waters are very impure; while in well-drained and mountainous country districts they are much purer. Dangerous organic matter may filter through many feet of soil and poison the water of a well or spring. Shallow wells usually contain much more organic and less mineral matter than deep wells, and are therefore more likely to contain dangerous or unwholesome matters. Shallow wells are essentially a pit for the reception and accumulation of the drainage from the surrounding soil. For convenience they are usually situated near the dwelling, where the soil receives more or less household waste of various kinds, and are often placed near a cesspool or privy vault. The effect of the geological character of the soil is almost entirely obliterated by this local impurity. Such waters, even when disgustingly impure, are usually bright, sparkling and palatable, and are often much approved by those accustomed to their use. Deep wells may be regarded as those which draw their supply from a depth of 100 feet or more from the surface. In cases where the supply is drawn from below a dense bed of clay or of impervious rock, the well may be considered deep, when such supply is much less than 100 feet below the surface. Deep wells may be regarded as artificial springs, as both are subjected to the same conditions.

Artesian wells are artificial springs formed by boring into the earth in a low-lying district surrounded by high ground, until a layer of rock or gravel is reached, situated between two impermeable layers and containing water. The strata must be so curved that their outcrop is on a higher plane than the surface of the well. In such cases the water rises to the surface without pumping, and its character is determined by the nature of the rocks in which the water is found.

Surface Waters.—These comprise river, pond, lake and sea water. The water supply of large cities is usually taken from this class of waters, and consists of spring water, and rain water which has fallen upon a considerable surface of country. Surface waters usually contain a large proportion of organic and mineral matters. Surface water, draining from a cultivated district, contains more organic and mineral matter than that from uncultivated districts, and the character of it is considerably influenced by application of fertilizers to the land. River waters are often contaminated by the discharging of sewage and refuse into them from various manufactories along their banks.

Characteristics of a Good Drinking Water.—1st. It should be clear and limpid. Cloudy and muddy waters should be avoided. 2d. It should be colorless. A greenish or yellowish color is usually due to vegetable or animal matter in solution, or to organisms. 3d. It should be odorless; especially free from sulphuretted hydrogen or putrefactive animal matter. 4th. It should not be too cold, but should have a temperature of from 8° C. (46°F.) to 15.5° C. (60° F.). 5th. It should have an agreeable taste; neither flat, salty, nor sweetish. A certain amount of hardness and dissolved gases give a sparkling taste. It should contain from 25 to 50 c.c. of gases per liter, of which 8 to 10 per cent. is carbon dioxide, and the rest oxygen and nitrogen. The air of natural waters is richer in oxygen than the atmosphere above them, viz.: about 33 per cent. of oxygen and 67 per cent. of nitrogen, when the water is fully saturated, which is not always the case. Highly contaminated waters usually contain less oxygen than the above proportion, because it is used up in oxidizing the organic matter. 6th. It should be as free as possible from dissolved organic matter, especially of animal origin. 7th. It should not contain too great an amount of hardness. A certain quantity of saline matter is necessary, however, to give it a good taste. It should not contain over 3 or 4 parts of chlorine in 100,000 parts of water.

Sanitary Water Analysis.—We have seen that natural waters are never pure, but contaminated by various kinds of foreign matter to which they have been exposed. These impurities may be harmless to the human economy, or they may be very harmful. It is the object of the analyst to determine, as nearly as possible, the nature and amount of impurities found in a water, so as to form an opinion as to its healthfulness.

It has been proven, beyond doubt, that water is a fruitful disseminator of disease. It is believed that the disease produced in such cases is due to microscopic organisms, and that the organic matter of the water simply furnishes a suitable solution in which they may live and grow. It is also known that these organisms grow best in solutions of organic animal matter, and this animal matter may be the carrier of the disease germs; hence, waters contaminated with animal matters are looked upon as much more dangerous than those containing vegetable matter.

If the above idea be correct, it is evident that chemical analysis cannot detect the disease-producing element, although it can tell **pure** from **impure** water.

Several methods are in use among chemists for the purpose of forming an opinion as to the character of drinking waters. The elements usually relied upon in a sanitary examination are the total residue left on evaporation, the loss in weight of this residue on ignition at a dull red heat, the chlorides, the nitrates and nitrites, ammonia, organic carbon and nitrogen, and the quantity of oxygen the water will absorb from an acid solution of potassium permanganate. Poisonous metals should, of course, be looked for where there is any suspicion of their presence.

Total Residue.—The amount of residue left on evaporation serves, in a crude way, to indicate the amount of solids, but is only approximate and of no significance unless it reaches more than 30 or 40 grains per gallon. This residue will, of course, vary with the hardness, or the amount of soluble constituents in the soil. By heating the solids to a dull red heat we expel all volatile and organic matter, including the water held by the calcium sulphate at the temperature of 100° C. (the temperature generally used in drying the residue), some carbon dioxide from carbonates, and oxides of nitrogen from nitrates and nitrites. The residue left after ignition gives a rough idea of the mineral matters present, and the loss on ignition should never reach 50 per cent. of the total residue.

Something may be gained by observing the color of the residue left on evaporation, which should be of a pure white color. It should blacken but very little on heating, and should give off no fumes. The residue of bad waters blackens very considerably, or gives off the odor of burning horn, or of nitrous fumes.

Chlorine in potable waters is very largely derived from the sodium and potassium chlorides of urine and sewage. The average amount of chlorine in urine is not far from 5 parts per 1000, or 500 parts in 100,000 parts of water. The average found in sewage is about 11.5 parts per 100,000. Over 5 parts of chlorine per 100,000 may be considered, in most cases, to be due to pollution of the water by sewage or animal excretions. This will be modified by the chlorine found in the purest waters of the same class of that district. The source should always be taken into account in judging of the quality of a water. Proximity to the sea does not materially affect the amount of chlorine in well waters. Too much dependence should not be placed upon the amount of chlorine in the water as a means of judging of its purity, for vegetable matter may exist in dangerous quantity without its presence being indicated by the chlorine present. Chlorine is estimated by a standard solution of argentic nitrate.

This solution is prepared by dissolving 4.8022 grms. of crystallized silver nitrate in a liter of water. Each c.c. of this solution will precipitate 0.001 grm. of chlorine. 100 c.c. of the water under examination is measured out into a beaker, just enough potassium chromate is added to give a distinct yellow tint, and then the above silver solution is run in from a graduated burette, a few drops at a time, until a slight red tint appears, showing that the chlorine has been precipitated and that the silver is beginning to precipitate the chromic acid as red silver chromate. From the amount of silver solution used we may easily calculate the amount of chlorine present, for 1 c.c. of the silver solution precipitates 1 milligram of chlorine. The number of c.c. of the silver solution used multiplied by 10 will give the mgrms. of chlorine in 1 liter of water, or the parts per million. With many natural waters it is best to evaporate off about half the volume before titration.

Hardness.—The hardness of water is produced principally by the acid carbonates and the sulphates of calcium and magnesium. The acid carbonates are decomposed by boiling, and the neutral salts precipitated:—

$$CaH_2(CO_3)_2 = CaCO_3 + H_2O + CO_2.$$

Hardness due to these salts is called "temporary," while that due to the sulphates of these metals is called "permanent."

The hardness of water seems to have little or no influence upon the health of those who use it. Temporarily hard waters may be softened by adding lime in sufficient quantity to neutralize the excess of carbonic acid in the water, when the carbonate ($CaCO_3$) or ($MgCO_3$) is formed, which settles to the bottom. The alkaline carbonates (Na_2CO_3) and (K_2CO_3) may be used to precipitate permanent hardness and soften the water. Wood ashes, which contain the latter of these salts, is frequently used by washerwomen to soften water for washing clothes.

Hardness is estimated by means of a standard solution of soap. Many samples of water possess both temporary and permanent hardness, and sometimes it is desirable to estimate them separately. For this purpose the total hardness is estimated in one sample, and the hardness in another sample is determined after boiling and separating the temporary hardness. The difference of the two gives the temporary hardness. When soap is added to a hard water, the calcium and magnesium salts are precipitated according to the following equation:

$$\underset{\text{Calcium Acid Carbonate.}}{H_2Ca(CO_3)_2} + \underset{\text{Sodium Stearate.}}{2NaC_{18}H_{35}O_2} = \underset{\text{Calcium Stearate.}}{Ca(C_{18}H_{35}O_2)_2} + \underset{\text{Sodium Carbonate.}}{Na_2CO_3}\ H_2O + CO_2 \text{ or}$$

$$\underset{\text{Calcium Sulphate.}}{CaSO_4} + \underset{\text{Sodium Stearate.}}{2NaC_{18}H_{35}O_2} = \underset{\text{Calcium Stearate.}}{Ca\ (C_{18}H_{35}O_2)_2} + \underset{\text{Sodium Sulphate.}}{Na_2SO_4}.$$

The calcium stearate in both cases is precipitated as a white curdy-like mass. The hardness is estimated by taking advantage of these reactions. There is required for the estimation, a standard solution of soap made as follows: 10 grams of shavings from a new cake of air-dried castile soap, are dissolved in a liter of about 60 per cent. alcohol. Filter if not clear, and keep it in a tightly stoppered bottle. To determine the strength of the soap solution, dissolve exactly 1 gram of pure $CaCO_3$ in a little HCl, neutralize with ammonium hydroxide, and add sufficient water to make 1 liter. 1 c.c. of this solution will contain the equivalent of 0.001 gram of calcium carbonate. Measure out 10 c.c. of this solution into an 8 oz. glass-stoppered bottle, add about 90 c.c. distilled water, and run in the soap solution, drop by drop, from a burette, shaking after each addition, until a lather is formed, which remains for five minutes. Note the number of c.c. of soap solution used, and calculate the amount of calcium carbonate precipitated by 1 c.c. of the soap solution as follows. We now repeat this experiment with 100 c.c. of pure distilled water. The amount of the soap solution required to produce a permanent lather in the distilled water, must be deducted from the amount used in the above test. Usually it will not be far from one-half to one c.c. The 10 c.c. of the solution of $CaCO_3$, used in the above-mentioned test, contained the equivalent of 10 mgrms. of $CaCO_3$. Suppose, in the above-mentioned test, 8.5 c.c. of the soap solution were used to produce a permanent froth and 0.5 c.c. were required by the distilled water. Then 8 c.c. were used to precipitate the 0.10 gram of $CaCO_3$. Each 1 c.c. of this solution precipitated $\frac{1}{8}$ of 10, or 1.25 mgrms. of $CaCO_3$.

The estimation of the hardness of a water is conducted exactly as the above process for standardizing the soap solution, except that 100 c.c. of the water under examination is placed in an 8 oz. bottle and the soap solution run in from a burette until a permanent lather is obtained. Read off the number of c. c. of soap solution added, and multiply this by 10, which will give the hardness reckoned as $CaCO_3$ in mgrms. per liter, or parts per million. The hardness of waters varies so much that no average can be given. A water that does not contain more than 56 parts of hardness per million may be regarded as soft water, while one containing 150 is a hard water.

Nitrates and Nitrites.—These salts are usually looked upon as evidences of former contamination of a water by nitrogenous organic matter. The decomposition of organic matter of animal origin, in waters containing dissolved oxygen, yields nitrous and nitric acids, which combine with bases present to form salts of these acids. Rain water contains a small quantity of these acids, but a larger quantity indicates that the water is undergoing, or has undergone, a natural process of purification from animal matters. This change is partially due to direct oxidation, but more particularly to the action of certain microörganisms which have the peculiar power of converting nitrogenous organic matter into nitrites and nitrates, both in water and in soil. The process of disposing of nitrogenous organic matter, in natural waters, or animal refuse, is to convert the nitrogen into ammonia, then into nitrous acid, and finally into nitric acid. The quantity of these compounds found, usually indicates the amount of matter thus decomposed. This purifying process goes on more slowly in river and lake waters than in ground water, because the exposure to oxygen is more complete while filtering through the soil, than in a body of water. Deep wells may be allowed to contain more nitrates than shallow ones, for the organic matter may all be destroyed by filtering through the soil into a deep well, while in the shallow one some organic matter, germs, and spores capable of causing disease, may pass undecomposed through the shorter distance. A careful estimation of nitrates gives, therefore, considerable knowledge of the past history of a water, and is regarded by chemists as of great importance.

A very easy and delicate test for nitrates and nitrites in water is the following: Make a solution of *diphenylamin* in pure, strong, sulphuric acid free from nitric or nitrous acids, as shown by a duplicate test with distilled water, adding a little pure water to make a clear solution.

To the suspected water add one-half its volume of the sulphuric acid, then a few drops of the above solution. If nitrates or nitrites are present, a deep blue solution will be formed at once. This test may be used by any one, and will give some idea of the safety of a drinking water.

To detect the presence of nitrites, a solution of meta-phenylendiamin in pure sulphuric acid may be used. When nitrites are present the solution assumes a yellow to brown color, according to the quantity present.

If to 100 c. c. of water we add 1 c. c. each of a saturated solution of naphthylamin chloride, sulphanilic acid, and diluted hydrochloric acid (1 to 3 of water) there appears, if nitrites are present, a pink color, the intensity of which is proportional to the quantity present.

A *quantitative estimation* of the nitrites requires the following reagents: 1. Sulphanilic acid, 1 grm., dissolved in 100 c. c. of hot water. 2. Naphthalamin hydrochlorate, 0.5 grm., dissolved in 100 c. c. of boiling water, kept in a glass-stoppered bottle, with a little pulverized carbon added to decolorize the solution. Filter or decant from the carbon when required for use.

3. Dissolve .275 grm. of dry silver nitrite in hot water, add a slight excess of sodium chloride and dilute with pure water to 250 c. c. After the silver chloride has settled, remove 10 c. c. of the clear solution and dilute with water to 100 c. c. One c. c. of this solution, which is used in the analysis, is equivalent to .01 mgrm. of nitrogen.

The process: 100 c. c. of the water is placed in a cylinder, previously cleansed, and two drops of strong hydrochloric acid added. Add 1 c. c. of the sulphanilic acid solution, followed by 1 c. c. of the solution of naphthalamin hydrochlorate. Mix and cover to exclude dust, and let stand for thirty minutes. One c. c. of the standard nitrite solution (No. 3) is placed in another glass cylinder, water free from nitrites is added to make 100 c.c., and the whole treated with the same reagents as the above. At the end of a half-hour the two solutions are compared. The colors are brought to the same tint by diluting the darker, and the calculation made as to the amount of nitrogen, as nitrite, in the 100 c.c. Suppose, for example, the 100 c.c. of the water requires dilution to 125 c.c. in order to make this tint agree with that produced by 1 c.c. of the standard sodium nitrite solution, which contains .01 mgrm. of nitrogen as nitrite; then $100 : 125 :: .01 : x = .0125$. That is, the water contains in 100 c. c. .0125 mgrm. of nitrogen in the form of nitrites, or .125 mgrm. per liter, or .125 parts per 1,000,000. Leeds places the limit for American rivers at .03 per 100,000, and Mallet places the average in good waters at about .014 part per million. When the quantity exceeds .02 in 100,000 it is considered as indicating previous contamination by organic matter whose nitrogen has been converted into nitrous acid.

The nitrates are estimated by acidulating 500 c.c. of the water with oxalic acid, pouring half of it into each of two wide-mouthed bottles. Into one of these put a copper-zinc couple, made by taking a piece of sheet zinc (4 by 6 in.), rolling it into a loose coil, and immersing it in a 1.5 per cent. solution of copper sulphate until the surface is covered with an even layer of copper * Cork both bottles and let them stand for 24 hours. Remove 50 c.c. from each bottle and Nesslerize as directed under ammonia. The difference between the two readings gives the ammonia due to the reduction of the nitrites and nitrates present. The nitrogen in the previously determined nitrites must be subtracted, when the remaining nitrogen will be that from the nitrates. If the nitrogen, as nitrates, exceeds six parts per million, the water is suspected of having been polluted.

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* Sodium amalgam has been recommended instead of the zinc-copper couple for reducing the nitrates and nitrites.

Moist combustion or oxygen consuming power.—By this is meant the oxidation of the organic matter found in a water, by adding to it a measured quantity of potassium permanganate, with some sulphuric acid, and determining the oxygen absorbed from this salt by the organic matter present. This method cannot distinguish between vegetable and animal matters, neither will it measure the oxygen consumed in oxidizing nitrites to nitrates, or ferrous to ferric salts. In the presence of these salts it may give erroneous results. Most chemists regard the process as of some value in giving an idea of probable pollution by organic matter, as it has been shown that dangerous organic matter is more easily oxidized than that which is harmless.

The **quantitative process** requires the three following solutions: 1. **Potassium permanganate solution.** It is conveniently made of such strength that 1 c. c. will yield 0.1 mgrm. of oxygen for oxidation. Such a solution will contain 0.3952 grm. of the salt in 1 liter of distilled water. 2. **Solution of oxalic acid.** Dissolve 0.7875 grm. crystallized oxalic acid in 1 liter of water. One c. c. of this solution, when titrated with the potassium permanganate solution, in the presence of sulphuric acid and while hot, should just decolorize 1 c.c. of permanganate solution. 3 **Dilute sulphuric acid,** 1 part strong acid to 3 of water. Add enough permanganate solution to give a faint pink tint after standing four hours.

Method of Procedure.—Measure 200 c.c. of the water under examination into a half liter flask, add 10 c. c. of the diluted sulphuric acid, and enough of the potassium permanganate solution from the burette to give it a marked red color. Boil for ten minutes, adding more of the permanganate solution from time to time, if necessary, to maintain a red color of about the same intensity. Remove the lamp, and 10 c. c. of the oxalic acid solution to destroy the color, and then add more of the potassium permanganate from the burette until a faint pink tinge again appears. From the total amount of permanganate used, deduct the 10 c. c. which were used up by the oxalic acid solution. The remainder will give the amount of permanganate used by the water, or the number of mgrms of oxygen actually absorbed by the water. This quantity multiplied by 5 will give the number of mgrms. of oxygen absorbed by a liter of water under the above conditions, or the parts per million. Waters absorbing more than 2 parts of oxygen in 1 million should be considered as of doubtful purity. Those containing 5 parts should be regarded as organically impure. Leeds gives as a limit for American rivers from 5 to 7 parts per million.

Another process allows the mixture of the water, acid and permanganate to remain at the room temperature for a longer time.

Five stoppered bottles, holding 500 c. c. (a pint), are thoroughly cleansed with pure sulphuric acid. To each add 250 c. c. of the water to be tested, and 10 c. c. of the sulphuric acid. Then add varying amounts of the permanganate solution, say 2, 4, 6, 8 and 10 c. c. respectively. They should be inspected at the end of 1, 2, 3, 4 and 12 hours, and the effect noted. If all the bottles should be discolored before the end of the fourth hour, 10 c.c. is added to each, and the result again watched. In fairly good waters not more than the first 2 or 3 will decolorize in 4 hours. That is, 250 c.c. of water should not absorb more than 1.5 to 2 mgrms. of oxygen.

This process is simple, and requires little skill when the solutions are once prepared.

Ammonia.—The spontaneous decomposition of organic matter in water first affords ammonia, then nitrites, and finally nitrates. This fact is so generally conceded as to make an estimation of the ammonia found in a water, a very important part of the sanitary examination.

The ammonia is generally spoken of as free ammonia, or more properly **ammonium salts**; and **albuminoid ammonia,** or **ammonia from organic nitrogen.** The sanitary examination of a water should always include a quantitative estimation of the ammonia and organic nitrogen.

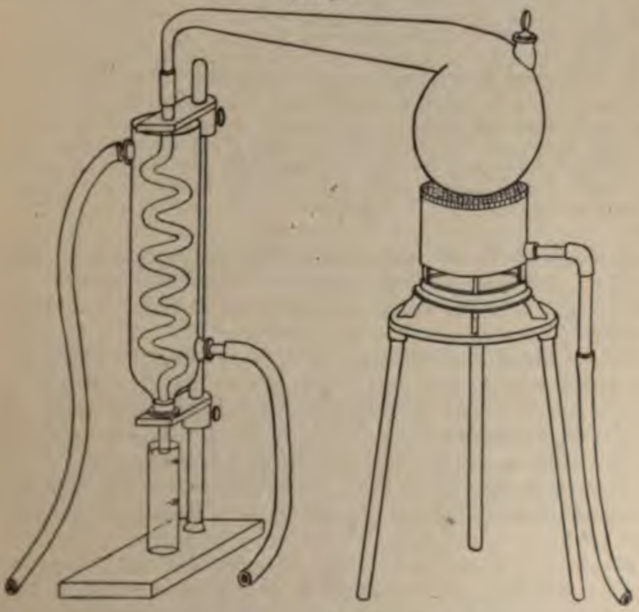
The method usually adopted for this purpose is that known as the Wanklyn process, and is the one which yields the best results

The process requires several solutions and considerable care in manipulation in order that the results may be reliable. The solutions required are: 1. **Nessler's solution,** made by dissolving 35 grms. of potassium iodide in 100 c. c. of water, and 17 grms. mercuric chloride in 300 c. c. of water. When solution is complete, add the latter solution to the former until a permanent precipitate is produced. Then dilute with a 20 per cent solution of sodium hydroxide to 1 liter. Now add the mercuric chloride solution again until a permanent precipitate forms. Let settle till clear, and decant and use the clear solution. It improves on keeping, and will detect extremely minute quantities of ammonia. 2. **Sodium carbonate.** A saturated solution of pure freshly ignited sodium carbonate in water free from ammonia. 3. **Standard ammonium chloride solution.** Dissolve .314 grm. of ammonium chloride in 100 c. c. water. 1. c. c. of this solution is then diluted with 99 c. c. of ammonia-free water. This last solution will contain .00001 grm. of ammonia in each c. c. and is the solution employed in the analysis. 4. **Alkaline potassium permanganate.** Dissolve 8 grms of pure potassium permanganate crystals and 200 grms. of potassium hydroxide in water and make up to a liter. The solution is put into a flask, or retort, and distilled. The distillates are collected and tested with the Nessler's solution until they cease to give a reaction for ammonia, when the solution is ready for use. 5. **Water free from ammonia.** A good clear well or hydrant water is treated with a few c. c. of the sodium carbonate solution, and distilled until a small portion of the distillate shows no reaction with Nessler's test. The remainder, except the last portion, will usually be found to be absolutely free from ammonia. Or, we may add to the water a few drops of strong sulphuric acid and distil, rejecting the first one-tenth of the whole volume, when the remainder will usually be found to be free from ammonia.

The process.—100 c. c. of pure distilled water is put into a retort holding about a half liter. To this is added 2 c. c. of the sodium carbonate solution.

The retort is connected with a Liebig's condenser by an air-tight joint made by a piece of black rubber tubing of large calibre drawn over both the retort and condenser. The beak of the retort is bent at such an angle that the lower end may be attached to the block tin tube of the condenser, as shown by Fig. 52. A lamp is now brought under the retort and the water rapidly boiled until 10 c. c. of it shows no reaction with Nessler's reagent. 100 c. c. of the water under examination is now put into the retort by means of a funnel, and the boiling continued **slowly**, removing the distillate when 10 c. c. are collected. Four distillates of 10 c. c. each, usually contain all the ammonia existing in the water as salts of ammonia. Many prefer to use 500 c. c. of the water instead of 100 c. c. and distil off 50 c. c. of the solution for Nesslerizing. The author prefers the smaller quantities, using smaller tubes graduated at 10 c. c. The process of Nesslerizing is conducted as follows: 0 5 c. c. of the Nessler's solution is measured into each of the four distillates and mixed by agitation. The weaker ammonia solution is now added to 10 c. c. of the ammonia free water in another cylinder, until the color produced with 0.5 c. c. of Nessler's solution is equal to that in the first distillate removed. Each distillate is imitated by a known amount of ammonia in the same volume of liquid. Some chemists recommend to add ⅓ of that found in the first distillate as an average amount to be found in the remaining ones. When about 40 c. c. have distilled over, the lamp is removed and 10 c. c. of the alkaline permanganate solution is

FIG. 52.



added to the retort, and the distillation slowly continued, setting aside each distillate when 10 c. c. are collected. These distillates are again Nesslerized as in the case of the first distillate. The color of each cylinder is imitated in other cylinders with a known amount of ammonia and the amounts so obtained are added together to obtain the total amount of ammonia. After a little practice it will be easy to imitate the color of any distillate by this process. It is necessary to note not only the absolute quantity of **albuminoid ammonia**, but the rapidity with which it is set free and distilled over. If it comes very rapidly, it indicates that the organic matter is in a putrescent or decomposing condition. If, on the other hand, the ammonia distils gradually, it indicates the presence of organic matter in a comparative stable or fresh condition. It is best, therefore, to keep the record of each distillate so that the rapidity with which the ammonia is set free, as well as the actual amount, may be known. If the water yields no albuminoid ammonia, it is free from recently added organic contamination. Usually, however, it gives a very small amount. If it contain more than 0.1 mgrm. per liter, the water is looked upon as suspicious, and is to be condemned when it reaches .15 mgrm. per liter, or .15 part per million. If free ammonia is present in a considerable quantity, then the albuminoid ammonia becomes suspicious of contamination when it reaches over .05 mgrm. per liter. An opinion should not be formulated, however, without a knowledge of the source of the water examined. Free ammonia may exist in larger quantities in some deep wells without denoting dangerous contamination.

Biological Examination of Water.—In recent years it has been customary to determine the nature and number of the micro-organisms in water by the well-known bacteriological methods

Surface waters and many well waters contain a variety of living organisms which may be easily discovered by the aid of a microscope; such as the **daphinæ, cyclops, desmids, algæ, rotiferæ, amœbæ,** etc. These organisms feed mostly on suspended organic matter, and are not regarded as especially harmful, except in the case of the entozoa. Dissolved organic matter in a state of decomposition is generally indicated by the smaller bacteria.

The principal object in view, in these examinations, is to determine the number of organisms in a given volume, 1 c.c., of the water, and if possible to determine the character of these organisms. The cultivation of the organisms requires care and skill, and is even then open to great question as to the value of the results. Pathogenic bacteria have rarely been found by this method, and the chemical methods are still relied upon. While much is to be hoped for in the future, the process has not thus far given results, which, taken alone, can replace the older chemical methods above referred to.

We have thus briefly outlined the methods in use for testing drinking waters, for the purpose of giving the student some knowledge of the subject, without going into tedious details, which are intended only for the chemist, and which do not come within the scope of this work.

Purification of Water.—Water may be separated from suspended impurities by filtration, *i. e.*, by passing it through any porous substance not soluble in water, as clay, sand, charcoal, brick, unglazed earthenware, unsized paper, etc. For filtering large quantities of water for cities or manufactories, sand or brick is to be preferred. For filtering water for family use, a brick partition two or four inches thick, built from wall to wall, in a cistern, works well. The water is delivered in one apartment and pumped from the other for use. Or, a barrel in the bottom of which several holes are bored, may be filled with alternate layers of gravel, sand and charcoal, and placed over the mouth of the cistern or reservoir, through which the water may be filtered. Such a filter, when freshly made, will remove a part of the dissolved organic matters as well as suspended matters. The **silicated carbon** filters found in the market, made of pulverized carbon and cement, are much neater, and will also, when new, oxidize a portion of the dissolved organic matter in passing the water through them. Porous stone filters, made from a silicious stone, are to be found in the market, which filter rapidly and very satisfactorily. Spongy iron filters, made by roasting hematite with coal, are still more active in destroying organic matter and putrefactive germs. But few of the various forms of commercial filters remove micro-organisms from water; on the contrary, many of them, after being used for a short time, begin to contaminate the water with microscopic organisms which they harbor in their pores. Filters made of unglazed porcelain are now made which will remove micro-organisms from solutions. Sand filters are most efficient for filtering large quantities of water for the supply of cities.

In some cities a process of "scouring," or agitation of the water with angular sand, is practised. In others there is employed a combination of a precipitant of the organic matter and filtration. The precipitants are either alum or a ferric salt. The Hyatt and National systems operate on this principle, and are said to be efficient, where the amount of water to be treated is not too great. In the Anderson system the water is agitated with iron borings, in a revolving iron cylinder, which forms a certain amount of ferrous carbonate from the carbonic acid of the water. The temporary hardness is thus largely removed by removal of the carbonic acid. On exposure to air the ferrous carbonate is oxidized and ferric hydroxide is precipitated.

$$2FeCO_3 + O + 3H_2O = Fe_2(OH)_6 + 2CO_2.$$

The water is then filtered through sand. The organic matter is largely removed by this process, as is shown by analysis, and the organisms as well. The time of contact of the water and iron is about 3 or 4 minutes. This process has been tried in some large cities and is highly spoken of.

Organic matter may be largely removed from water by precipitation with alum or ferric chloride. When alum is added to a water, it is decomposed, with the formation of a hydroxide which, as it settles, carries down with it all suspended matters and a large part of the dissolved organic matter and microörganisms. From one to two grains to the gallon is sufficient. Ferric salts behave in a similar manner. Filtration through granulated iron, kept clean by agitation, and afterward filtering through sand, serves to remove a large part of the organic matter and microbes.

We have already referred to methods of precipitating the **hardness** from water. Distillation, as a means of purifying water, has also been referred to. Freezing purifies water, and removes, to a considerable extent, mineral as well as organic matter; but freezing cannot make a dangerous water safe. Numerous instances show that disease may be communicated as surely by ice as by unfrozen water.

Mineral Waters.—Under this name are included such waters as, from some dissolved substances, have a greater or less therapeutical value. These vary so much in the character of the dissolved substances, that no exact classification of them can be made; but they may be roughly classified as follows:—

1st. **Carbonated Waters,** those which are charged with carbon dioxide or carbonic acid.

2d. **Sulphuretted Waters,** those which contain sulphides of hydrogen, or one of the alkaline metals, in notable quantities. They are used for baths as well as for drinking.

3d. **Alkaline Waters,** those containing considerable quantities of carbonates or bicarbonates of the alkaline metals—sodium, potassium, or lithium.

4th. **Saline Waters,** those containing the neutral salts, such as the chlorides, bromides, or iodides of the alkalies or alkaline earths.

5th. **Chalybeate Waters,** those containing some one of the compounds of iron. Closely allied with these in properties are those containing manganese.

6th. **Acid Waters,** those containing free mineral acids, such as hydrochloric or sulphuric acids.

7th. **Thermal Waters,** or such as come to the surface at a temperature above that of 20° C. (68° F.). Some of these springs contain so little mineral matter as to be of no importance; the only value, if any, being in the temperature. They are used principally for baths.

Official Forms.—Aqua. Natural water in the purest attainable state. **Aqua destillata.** Take of water 1000 vols.; distil 100 vols., reject, then distil 800 vols. (U. S. P.) The transparency or color of distilled water should not be affected by lime water; nor by H_2S, $BaCl_2$, $AgNO_3$, or $(NH_4)_2C_2O_4$, etc.

The term **aqua,** in the U. S. P., is used to designate a solution of a gaseous or volatile body in water, as **aqua ammoniæ, aqua chlori.** A **Liquor** is a solution of a fixed or solid body, as **Liquor Ferri Nitratis; Liquor Plumbi Subacetatis.** A **Decoction** is a solution made with boiling water, usually of a vegetable product. An **Infusion** is a solution formed by subjecting the body for a short time to either cold or warm water. **Maceration** is the long-continued action of water at the ordinary temperature. **Digestion** is the same with hot, but not boiling water. **Lixiviation** or **leaching** is the process of pouring water through a porous mass of any substance, for the purpose of dissolving out soluble matters.

Physiological Use.—Water exists in all the tissues of the body, and in all foods and drink. A healthy adult takes, on an average, about 2.5 liters of water in 24 hours; and loses by the skin, lungs, kidneys and fæces a little more than this; the **excess** coming from the oxidation of the hydrogen of the food and and tissues. Water constitutes from 65 to 70 per cent. of the whole body, being in slightly larger proportion in the young than in the adult body. The water in the tissues serves as a solvent for the various proximate principles intended as nourishment for the tissues, or coming from their waste, and intended for excretion. The evaporation from the skin serves to carry off the superfluous heat of the body.

Hydrogen Dioxide, Hydrogen Peroxide (H_2O_2), Aqua Hydrogenii Dioxidi, U. S. P.—The simplest way of preparing a diluted solution of H_2O_2 is to pass a stream of CO_2 through water containing barium peroxide in suspension.

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2.$$

The insoluble barium carbonate may be separated by filtration, best through asbestos filters. This solution may then be concentrated by evaporation on a water bath, without much decomposition. In fact it is more stable than formerly supposed.

The commercial solutions usually contain about three per cent. of H_2O_2. Ethereal solutions are sold containing 5 and 25 per cent. In its purest form it is a syrupy, colorless liquid, having an odor resembling that of chlorine or ozone, and a tingling metallic taste. It is still liquid at — 30° C. (—22° F), but at a temperature of 100° C. (212° F.) it changes rapidly into water and oxygen. This change takes place slowly at ordinary temperatures. In diluted solution it is much more stable, and may be boiled without suffering decomposition. The solutions of this substance are decomposed by many fine metallic powers. In most of its reactions it acts as an oxidizing agent. Argentic oxide, however, is reduced to the metallic state by it.

Tests.—To the suspected solution, add a little starch solution, then some potassium iodide, and finally a few drops of a solution of ferrous sulphate. If any hydrogen peroxide be present a blue color will appear. Very delicate.

Uses.—Oxygenated water, or hydrogen dioxide, is used as a bleaching agent for the hair and skin, converting brunettes into blondes. It is often used to renovate old pictures, the whites of which have become dingy. It has been used as a disinfecting application to ulcers, in ozæna, diphtheritic and scarlatinal sore throats, or where the membrane has invaded the nose. It is also used as a test for pus in urine, with which it causes an effervescence. Mixed with ether, it forms the so-called "ozonic ether," used with tincture of guaiacum as a test for blood coloring matter, with which they strike an indigo blue color.

OXYGEN COMPOUNDS OF THE ELEMENTS OF THE CHLORINE GROUP, OR GROUP VII.

Fluorine forms no oxides or hydroxides.

Chlorine and Oxygen.—There are several oxides of chlorine known.

Cl_2O, **Hypochlorous Oxide or Anhydride.**
Cl_2O_3, **Chlorous Oxide or Anhydride.**
Cl_2O_4, **Chloric Tetroxide.**

They are all unstable compounds, very prone to decomposition, and of little importance.

Hypochlorous Anhydride, Cl_2O, obtained by acting upon mercuric oxide with dry chlorine, is a blood red mobile liquid below 20° C. (68° F.).

$$HgO + 2Cl_2 = HgCl_2 + Cl_2O.$$

Above this temperature it is a yellowish, pungent, gas, resembling chlorine in many of its properties. It is a more powerful bleaching and disinfecting agent than chlorine, owing to the ease with which it decomposes. Water dissolves 200 times its volume of it, forming a colorless solution of **hypochlorous acid**. It sometimes decomposes with a slight jar, or even spontaneously, with the separation of chlorine and oxygen. Hypochlorous acid is unimportant, but it forms a series of salts called **hypochlorites**. A solution of the sodium salt, **liquor sodæ chloratæ** (U.S.P.), (Labarraque's solution), potassium hypochlorite, **liquor potassii chloratæ**, and calcium hypochlorite, occurring in **chlorinated lime**, are the most important compounds.

Chlorous Anhydride, Cl_2O_3, may be formed by treating potassium chlorate, $KClO_3$, with diluted nitric acid in the presence of arsenious oxide. It is a greenish-yellow explosive gas, soluble in water, with which it unites to form chlorous acid, $HClO_2$, a very unstable body which has not been isolated, but which forms **chlorites**. None of these salts are of importance.

Chloric Tetroxide, Cl_2O_4, may be obtained, as a yellow explosive gas, by treating potassium chlorate with strong sulphuric acid. It is a powerful oxidizing agent. Below — 20° C. (—4° F.) it is an orange-red liquid. It forms no corresponding acid.

Chloric Acid ($HClO_3$) and **perchloric acid** ($HClO_4$) are also known, but are very unstable, and like those before mentioned, are powerful oxidizing agents. Potassium chlorate is the only salt of note, which will be described under potassium.

Bromine and Oxygen.—No oxides of bromine are known. There are, however, three acids known, corresponding to those of chlorine. They are **hypobromous acid**, $HBrO$, **bromic acid**, $HBrO_3$, and **perbromic acid**, $HBrO_4$. They are of little importance, and but one salt of the three acids is of interest to the physician, and that is **sodium hybromite**, $NaBrO$, used as a reagent for the estimation of urea. It is prepared in solution by adding bromine to a solution of sodium hydroxide, taking care to keep the mixture cool by immersion in cold water.

$$2NaOH + Br_2 = NaOBr + NaBr + H_2O.$$

Iodine and Oxygen.—There are three or four unimportant and unstable oxides of iodine known I_2O_3, I_2O_5, and possibly I_2O_7. Two oxygen acids are known, iodic, HIO_3, and periodic, HIO_4. The first is obtained by treating iodine with nitric acid, and the second by passing chlorine through an alkaline solution of sodium iodate.

The first, when pure, appears as a white crystalline solid, and the second as colorless crystals. Both are very soluble in water, are easily decomposed, and form corresponding salts.

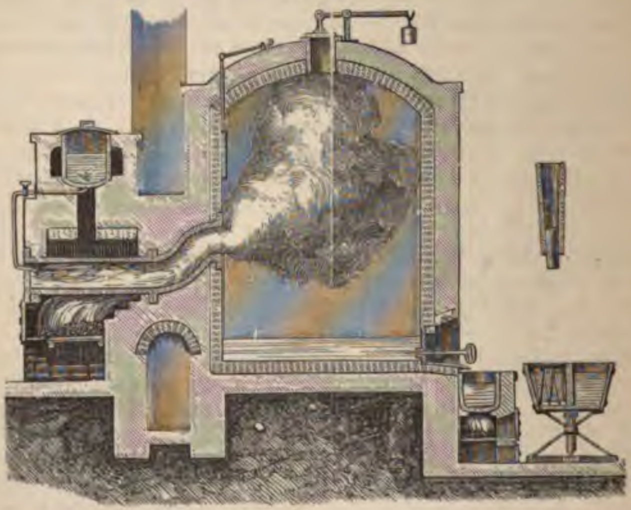
SULPHUR.

S = 32.

Sp. gr. 2. Density of vapor, 32. Melts at 115° C. (239° F.) Density of vapor at 500° C. (932° F.) = 95.94 = S_6. at 1000° C. (1832° F.) = 31.98 = S_2.

Occurrence.—Sulphur was known to the ancients. It occurs in volcanic regions, and is brought mostly from Sicily and Iceland. The sulphur occurs native, mixed with clay, from which it is separated by distillation. This element also oc-

FIG. 53.



REFINING OF SULPHUR.

curs as sulphates in the minerals, gypsum, $CaSO_4.2Aq$, Barite, $BaSO_4$, and as sulphides of iron, copper, nickel, and in fact, with many of the metals; also as a precipitate from sulphur waters. The following reaction explains its deposition from such waters:

$$2H_2S + O_2 = 2H_2O + S_2.$$

Preparation.—It is prepared from the native sulphur, mixed with more or less earth, found in the volcanic regions of Sicily by distilling it from the non-volatile impurities. A second distillation is necessary to prepare the refined sulphur of the market. The second distillation is conducted in a retort, the vapor being carried into a large chamber (Fig. 53), where, if the process is conducted slowly, it collects in the form of a crystalline powder called **flowers of sulphur,** or **sulphur sublimatum,** U. S. P. If the process is conducted more rapidly the chamber becomes hot, and the sulphur then condenses to a liquid at the bottom, whence it is drawn off into moulds, forming ordinary **roll sulphur** or **brimstone.**

Sulphur is also obtained in some localities from iron pyrites, by piling it in heaps mixed with wood, to which fire is applied. The ore gives up a part of its sulphur, which melts and runs into cavities made under different parts of the heap.

Properties—Physical.—Sulphur, in its ordinary form, is a lemon-yellow solid, melting at 115° C. (239° F.), and boiling at about 448° C. (839° F.), giving off a brownish-yellow vapor, which in condensing returns directly to the solid state. Sulphur is brittle, nearly tasteless, and odorless, a non-conductor of heat and electricity, and generates negative electricity when rubbed. It is insoluble in water, and almost so in alcohol. It is slightly soluble in anilin, phenol, benzene, benzine and chloroform. The best solvent is carbon disulphide, 100 parts of which dissolves 37 parts at ordinary temperatures.

Allotropic Forms.—Sulphur is capable of existing in three allotropic modifications; two crystalline, and one amorphous and plastic. The first variety is that found native, and occurs as octahedra. It is freely soluble in carbon disulphide, from which the crystals separate on evaporation. The second variety is produced by crystallization from sulphur melted at high temperatures. This variety occurs as yellowish-brown, transparent monoclinic prisms, of sp. gr. 1.98, insoluble in carbon disulphide, and gradually changing into the first variety. Since it crystallizes in two distinct systems, sulphur is said to be **dimorphous.** By heating sulphur, it melts at about 115° C. (239° F.)

to a yellowish liquid; on raising the temperature to about 200° C. (393° F.), it becomes viscid and dark colored, and cannot be poured from the vessel; at a higher temperature, approaching its boiling point, it again becomes liquid. If sulphur, in this second liquid state, be suddenly cooled by pouring into cold water, it becomes a soft, plastic, transparent mass, capable of being moulded like wax. This variety, like the preceding, gradually changes into the first variety, becoming opaque, yellow and crystalline.

Chemical.—When heated in the air, sulphur takes fire and burns with a pale blue flame, and evolves abundant fumes of sulphurous anhydride, SO_2. It is generally strongly electro-negative, and resembles oxygen in many of its compounds. In a few compounds it is electro-positive. It unites directly with many of the metals, especially when in the melted state, some metals taking fire and burning readily in its vapor. It forms the basis of a large and useful class of compounds, many of which resemble in composition the corresponding compounds of oxygen.

Thus, carbon disulphide, CS_2, corresponds to carbon dioxide, CO_2. Corresponding to hydrogen oxide, H_2O, we have hydrogen sulphide, H_2S, and to cyanic acid, CNOH, we have sulpho-cyanic acid, CNSH. Corresponding to carbonic acid, H_2CO_3, we have sulpho-carbonic acid, H_2CS_3.

Uses.—Sulphur is used in the arts, in the manufacture of sulphuric acid, H_2SO_4, as a bleaching agent for straw and woolen goods, and in the manufacture of matches and gun-powder. In medicine it is used as a parasiticide, and as a gentle laxative, although not as frequently as formerly. It is innocuous.

Official Forms.—1. **Sulphur sublimatum,** commercial flowers of sulphur. 2. **Sulphur lotum,** washed sulphur. Flowers of sulphur usually contain small quantities of sulphurous oxide, which is removed by digesting for three days in a diluted mixture of ammonia water and water, then thoroughly washing with water to remove the ammonia. 3. **Sulphur præcipitatum, lac sulphuris,** milk of sulphur, is prepared by boiling sublimed sulphur for one hour with freshly slaked lime suspended in water.

$$3Ca(OH)_2 + 6S_2 = 2CaS_5 + CaS_2O_3 + 3H_2O.$$

The filtered solution of CaS_5 and CaS_2O_3 is then diluted and treated with dilute hydrochloric acid as long as a precipitate forms.

$$2CaS_5 + CaS_2O_3 + 6HCl = 3CaCl_2 + 3H_2O + 6S_2.$$

The calcium chloride, being very soluble, remains in solution. The sulphur must be thoroughly washed with water until free from acid. It is a fine pale yellow, easily suspended in water and viscid liquids. **4. Unguentum sulphuris,** U. S. P., contains 30 per cent. of washed sulphur and 70 per cent. of benzoinated lard. Sulphur lotum enters into **pulvis glycyrrhizæ compositum.**

Sulphur and Hydrogen.—Two compounds of sulphur and hydrogen are well known—hydrogen sulphide, H_2S, and hydrogen persulphide, H_2S_2. The first only is of sufficient interest to merit description here. **Hydrogen sulphide, hydrosulphuric acid** and **sulphuretted hydrogen** are synonymous terms. It is found in volcanic gases, in some mineral springs, and as a result of the putrefactive decomposition of organic matter containing sulphur. At an elevated temperature, the two elements may be made to unite directly.

Preparation.—The usual method of preparing it is to act upon a sulphide, usually ferrous sulphide (FeS), with dilute sulphuric acid.

$$FeS + H_2SO_4 = H_2S + FeSO_4.$$

Properties.—H_2S is a colorless, transparent gas, of an unpleasant odor resembling that of rotten eggs, soluble in water, to which it imparts acid properties. It is somewhat heavier than air, its density being 17 and its sp. gr. 1.177. At a temperature of —70° C. (—94° F.), or under a pressure of 17 atmospheres at 10° C. (50° F.), it condenses to a colorless, mobile liquid, which at —85° C. (—121° F.) becomes an ice-like solid.

It burns with a blue flame, producing water and sulphurous oxide or anhydride, SO_2.

$$2H_2S + 3O_2 = 2H_2O + 2SO_2.$$

If the supply of oxygen is deficient, H_2O is produced, while the sulphur is deposited free. It is decomposed by chlorine, bromine, iodine and oxidizing agents in general. It is also decomposed by sulphurous oxide. A solution of sulphuretted hydrogen does not keep long when exposed to the air. The oxygen of the air unites with the hydrogen of H_2S, forming water, and causing the sulphur to be precipitated.

$$2H_2S + O_2 = 2H_2O + S_2.$$

When the gas is allowed to bubble through a solution of an alkaline hydroxide, the sulphur and oxygen exchange places with the formation of a sulphydrate.

$$KOH + H_2S = KSH + H_2O.$$

When it is passed through a solution of a metallic salt, it forms, in many instances, a sulphide of the metal.

$$CuSO_4 + H_2S = CuS + H_2SO_4.$$

It is, on this account, largely used in the laboratory as a reagent for the separation of the metals from one another. Minute quantities of H_2S may be detected by the odor, or by the brown or black color the gas imparts to a paper moistened with a solution of plumbic acetate. Its principal use is that of a reagent.

Physiological.—When inhaled, it is not an irritant, but a narcotic poison, even when largely diluted with air. According to Faraday, birds die in air containing $\frac{1}{1500}$ of it, and dogs in one containing $\frac{1}{800}$. According to Letheby, human beings cannot live in an atmosphere containing more than one per cent. Its action is principally a reducing one upon the hæmoglobin of the blood, and prevents this fluid from absorbing oxygen, although it probably does not combine with it. (Wurtz.) Hydrosulphuric acid is formed in the intestines from the decomposition of albuminous matters, especially where there is any impediment to digestion, or to the onward movement of the intestinal contents. It also sometimes occurs in abscesses, and in the urine and the bladder.

This gas is almost a constant ingredient in the gases of sewers and privy vaults, existing free, or combined with ammonium as ammonium sulphydrate. Poisoning by this gas may be acute or chronic. The latter is more common, producing a febrile state, with malaise and general debility. The fatal effects of sewer air are sometimes due to this form of poisoning. Occasionally this gas is so concentrated in sewers that those who enter them suffer with acute poisoning, falling almost instantly, and if not rescued, dying in a short time. The treatment, in such cases, should consist in giving the patient pure air, or oxygen, with brandy and water. Chlorine water, or a mixture of potassium chlorate and dilute hydrochloric acid, may be administered internally. When taken by the stomach, it is almost harmless; and in the form of natural mineral water, it is a popular remedy for rheumatism, gout and certain skin diseases.

Sulphur with Chlorine, Bromine and Iodine—Sulphurous Chloride (S_2Cl_2).—A yellow, volatile, fuming liquid, having a powerful solvent power for sulphur and sulphuric chloride, and formed by distilling sulphur in an atmosphere of chlorine gas.

It is decomposed by water, but mixes with benzene and carbon disulphide. SCl_2, and several oxychlorides, are known. **Bromine** unites directly with sulphur to form a red, unstable liquid, probably consisting mostly of S_2Br_2.

Iodine and Sulphur combine directly when gently heated, even under water. When 80 parts of iodine and 20 parts of sulphur are heated together, they form a steel-gray crystalline mass, S_2I_2, **sulphuris iodidum** (U. S. P. and B. P.), said to be a powerful remedy in certain skin diseases. It melts at 60° C. (140° F.), and is insoluble in water. Other iodides have been described, but are unimportant.

Sulphur and Oxygen.—The following oxides of sulphur are known:—

SO_2,	Sulphur dioxide, or Sulphurous anhydride.
S_2O_3,	Sulphur sequioxide.
SO_3,	Sulphur trioxide, or sulphuric anhydride.

Acids of Sulphur:—

1.	H_2S,	Hydrosulphuric acid.		
2.	H_2SO_2,	Hyposulphurous acid.		
3.	H_2SO_3,	Sulphurous acid.		
4.	H_2SO_4,	Sulphuric acid.		This acid has not been isolated, but its salts are known.
5.	$H_2S_2O_3$,	Thiosulphuric acid	(Hyposulphurous)	
6.	$H_2S_2O_7$,	Pyrosulphuric acid.	Nordhausen.	
7.	$H_2S_2O_6$,	Dithionic acid.		
8.	$H_2S_3O_6$,	Trithionic acid.		
9.	$H_2S_4O_6$,	Tetrathionic acid.		
10.	$H_2S_5O_6$,	Pentathionic acid.		

A few only of this large number of compounds are of sufficient importance to be described here.

Sulphurous Oxide or **Anhydride**, SO_2—**Preparation.**—1. It may be prepared by burning sulphur in the air. 2. By heating sulphuric acid with copper turnings, sulphur, or carbon. According to the U. S. P., and B. P., charcoal is used:—

$$2H_2SO_4 + C = 2H_2SO_3 + CO_2.$$

Properties—Physical.—A colorless gas, having a pungent, suffocating odor, and a disagreeable acid taste. It is very soluble in water, with which it combines to form an unstable sulphorous acid, **acidum sulphurosum,** U. S. P., emitting the odor of the gas. It is very soluble in alcohol. Sp. gr., 1.035 at 15° C. The density of the gas is 32; sp. gr. (Air = 1) 2.234.

Below —10° C. (14° F.), it is a colorless mobile liquid, which solidifies at —75° C. (—103° F.).

Acidum sulphurosum is a liquid containing not less than 6.4 per cent of the gas, by weight.

Chemical.—SO_2 is non-combustible, and will not support combustion or respiration. It combines with water to form sulphurous acid, and hence is an anhydride. Nascent hydrogen reduces it to H_2S and water. It is a valuable reducing agent, easily taking up oxygen to form sulphuric anhydride or acid. It is a bleaching, disinfecting and deodorizing agent of considerable value. It bleaches moist vegetable colors, although not permanently destroying them. The colors may be restored by an alkali, or by weak chlorine water. It is used principally for straw, silk and woolen goods. It decomposes hydrogen sulphide, and when concentrated, destroys many forms of microscopic life, and is much used as a disinfectant of rooms after contagious diseases. Although not so active as chlorine, it is preferred, because it does not corrode metals or bleach fabrics, if dry. To apply it, close the room and burn about three pounds of sulphur for every 1000 cu. ft. of air, leaving the room closed for from 6 to 8 hours.

Sulphurous acid forms two series of salts, the neutral and the acid salts. They are used as antiferments or antizymotics.

Uses.—They are used internally, and as sulphites and thiosulphates (hyposulphites) in zymotic diseases, gastric fermentations, sarcina, etc., also locally, in erysipelas and poisoned wounds. The sulphites and thiosulphates of the alkaline metals are used for the same indications as the acid. Thiosulphate of sodium is prepared by digesting sulphur with sulphite of sodium. It is used in photography and electro-metallurgy, as a solvent for the silver salts. Dose of the acid, 1 to 4 c. c. (MXV to fʒj) largely diluted. Dose of sodium sulphite or thiosulphate, 0.650 to 3,000 (gr. x to l)

Sulphuric andydride (SO_3), is obtained by distilling **Nordhausen acid,** as white, silky prisms, hissing when dropped upon water, from the energy with which they combine. Melts at 18.3° C. (65° F.), and boils at 43° C. (110° F.). It does not redden dry litmus paper. It has a powerful affinity for water, absorbing it from the atmosphere. It is only of scientific interest.

Sulphuric Acid, Hydrogen Sulphate, Oil of Vitriol, $H_2SO_4 = 97.82$.—The commercial acid is prepared in large quantities directly from sulphur or iron pyrites. The process is conducted in large chambers lined with sheet lead. Into these chambers sulphurous oxide pours from a furnace in which sulphur is burned or pyrites roasted, along with a free supply of air.

$$S_2 + 2O_2 = 2SO_2.$$

In the same furnace is placed a crucible containing sodium nitrate and sulphuric acid, for the purpose of preparing and volatilizing nitric acid, which is carried into the chamber with the SO_2 and air.

$$2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3.$$

The nitric acid gives up a part of its oxygen to oxidize a portion of the SO_2 to SO_3.

$$2HNO_3 + 3SO_2 = 3SO_3 + H_2O + N_2O_2.$$

The SO_3 combines with the water thus produced, and with more water which is supplied by a jet of steam thrown constantly into the chamber.

$$SO_3 + H_2O = H_2SO_4.$$

The N_2O_2 has the power of taking up oxygen from the air and becoming N_2O_4,

$$N_2O_2 + O_2 = N_2O_4,$$

which in turn parts with this oxygen to oxidize a new quantity of SO_2.

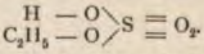
$$N_2O_4 + 2SO_2 = N_2O_2 + 2SO_3.$$

Thus the process is kept up as long as the SO_2, air, steam and $N_2O_2^4$ are supplied. The acid condenses with the water on the floor of the chambers, and when it reaches a sp. gr. of 1.55 (**chamber acid**) it is drawn off into large leaden pans and evaporated to a sp. gr. of 1.746 (**pan acid**), containing 78 per cent. of H_2SO_4, when it begins to dissolve the lead. It is then drawn off into platinum stills and the concentration completed.

Properties.—The commercial acid is a heavy, corrosive, oily liquid, often of a brownish tint, and has a sp. gr. of 1.830 to 1.845. It mixes with water in all proportions, combining with a certain quantity to produce H_4SO_5, and finally producing ortho-sulphuric acid, H_6SO_6, with the production of considerable heat. The concentrated acid attracts moisture, and is used as a desiccating agent. Gases, allowed to bubble through it, are deprived of their moisture. It chars organic matter and corrodes animal tissue. Paper dipped in a cooled mixture of two parts of the acid and one of water, and then quickly washed, is converted into **parchment paper.** Starch or cellulose, when boiled with the dilute acid, is changed, by hydrolysis, into glucose or grape sugar; and cane sugar into glucose and levulose. In this action it behaves like the unorganized ferments, diastase, pepsin, trypsin, etc., and illustrates the so-called catalytic action of certain bodies. The dilute acid is a solution of H_6SO_6 in water. On boiling this with the above-named bodies, it imparts a portion of its water to the organic body, and takes up more water from the solution to supply its place. Sulphuric acid is a powerful dibasic acid, forming a series of salts called **sulphates,** all containing the SO_4 group of atoms. It also forms a series of acid sulphates—$HKSO_4$. $HNaSO_4$. Owing to the powerful affinities of this acid, it usually removes the metal or positive radical from other acids and sets them free. It forms insoluble precipitates with solutions of barium, lead, strontium and with calcium in concentrated solutions. This should be remembered in adding it to prescriptions. The other sulphates are soluble in water.

Medical Effects.—When dilute, it is **tonic** and **astringent.** Concentrated, or in large doses, it is a corrosive poison. Antidote—lime, magnesia, sodium bicarbonate, or other alkaline body, best given in milk.

Official Forms.—**Acidum sulphuricum,** U. S. P., sp. gr. 1.84, is used only in making other preparations. It contains not less than 92.5 per cent. by weight of absolute sulphuric acid. It is a colorless, inodorous, and very corrosive liquid, having an oily consistency, and a very strong acid reaction. **Acidum sulphuricum dilutum,** U. S. P., sp. gr. 1.070 at 15° C. (59° F.), containing 10 per cent., H_2SO_4. B. P., sp. gr. 1.094, containing 13 per cent. H_2SO_4 **Acidum sulphuricum aromaticum,** U. S. P., should contain about 18.5 per cent. of absolute sulphuric acid, or about 20 per cent. of the official acid. It is an alcoholic solution, containing also tincture of ginger and oil of cinnamon. It contains ethyl sulphuric acid.



$$\left.\begin{matrix} H-O \\ C_2H_5-O \end{matrix}\right> S = O_2.$$

Tests for Sulphuric Acid and Sulphates.—1. Barium chloride gives a white ppt., insoluble in all acids.

2. Lead acetate gives a white ppt., slightly soluble in hot concentrated acids.

3. An insoluble sulphate may be detected by fusing it together with some sodium and potassium carbonate, dissolving out the alkaline sulphate with water and testing with barium chloride.

Fuming Sulphuric or Nordhausen acid ($H_2S_2O_7$), is obtained by distilling ferrous sulphate. The first portions are a white, crystalline solid, fusing at 35° C. (95° F.), and having the above composition.

The commercial acid is a brown, oily liquid, hissing when dropped into water. Some chemists regard it as a solution of SO_3 in H_2SO_4. When heated, it gives off SO_3 and H_2SO_4.

$$H_2S_2O_7 = H_2SO_4 + SO_3.$$

It is used in manufacturing alizarin, eosin, etc., and as a solvent of indigo. It forms a series of salts called disulphates.

Selenium and Tellurium.

Se 78.87. Te 125.

These elements are rare and of no special interest to the physician or pharmacist.

GROUP V.—NON-METALLIC ELEMENTS

OR

NITROGEN GROUP.

Nitrogen, N = 14.03 III or V.
Phosphorus, P = 31. III or V.
Arsenic, As = 75. III or V.
Antimony, Sb = 120. III or V.
Bismuth, Bi = 208. III or V.

Group Characteristics.—A well-defined group with nitrogen at the negative end and bismuth at the positive. The atomic weights form a graded series from 14.01 to 208.9. The first is a gas; the second a volatile solid; the third a volatile, crystalline, metallic-looking body, showing a slight tendency to alloy with metals and combine with acids; the fourth less easily volatilized, crystalline, possessing a brilliant lustre, alloying with metals, and showing a tendency to act the positive rôle with acids; the fifth, also crystalline, having a metallic lustre, and showing more marked positive tendencies. They are all both triad and pentad, and form two series of compounds.

The following will exhibit the relations of some of the most important compounds:—

Hydrides.	Chlorides.	Oxides.	Sulphides.
NH_3	NCl_3 ...	N_2O_3, N_2O_5	... ...
PH_3	PCl_3, PCl_5	P_2O_3, P_2O_5	P_2S_3, P_2S_5
AsH_3	$AsCl_3$, $AsCl_5$	As_2O_3, As_2O_5	As_2S_3, As_2S_5
SbH_3	$SbCl_3$, $SbCl_5$	Sb_2O_3, Sb_2O_5	Sb_2S_3, Sb_2S_5
...	$BiCl_3$, ...	Bi_2O_3, Bi_2O_5	Bi_2S_3, ...

NITROGEN.

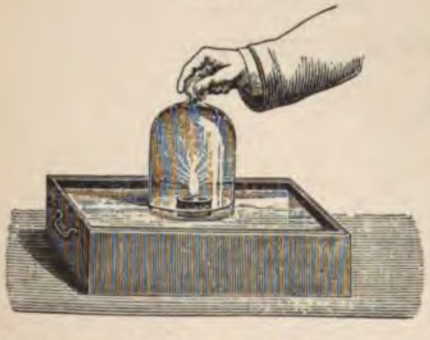
Symbol, N. At. Wt. 14. Equivalence, I, III or V. Density, 14. Wt. of 1 liter, 1.256 grms. Sp. gr. (Air = 1), 0.971.

Occurrence.—It exists free in the air, mixed with oxygen and argon. It is also found free in the gases of the stomach, the large and small intestines, the blood, the urine, etc. Combined, it occurs as nitrates of potassium, sodium and calcium; in ammonia, and in vegetable and animal bodies of the proteid group.

It was discovered in 1772, by Rutherford, who called it "Mephitic Air."

Preparation.—It is prepared from the air, by burning phosphorus in a confined space until the oxygen is removed (Fig. 54), or by passing air over copper or iron turnings heated to redness; the nitrogen prepared by both methods contains small quantities of other gases found in the air. To prepare it pure, heat ammonium nitrite (NH_4NO_2).

FIG. 54.



$$NH_4NO_2 + \text{heat} = 2H_2O + N_2$$

Properties—Physical.—A colorless, transparent, odorless, tasteless, incombustible gas, not a supporter of combustion or of animal respiration. It is not poisonous; very sparingly soluble in water or alcohol. One part of water dissolves, at the ordinary temperature and pressure .025 part of this gas. Chemically, nitrogen is characterized by its inertness. It unites directly with magnesium, boron, vanadium and titanium. Indirectly, it forms a great number and variety of compounds, many of which are unstable. Under the influence of electric discharges nitrogen can be caused to unite with hydrogen to form ammonia,

NH_3, and with oxygen to form nitrous oxide. From this source most of the nitrogenous products necessary to sustain plant life are primarily derived.

THE ATMOSPHERE.

The Atmosphere is a colorless, invisible, odorless mixture of gases, which surrounds the earth. It is very elastic, and is therefore most dense nearest the earth's surface, upon which it exerts a pressure of about fifteen pounds to every square inch. Air was first weighed by Otto Gerecke. 1000 c. c. of air at 0° C. and 760 millimeters of pressure weighs 1.293 gram. It is 14.44 times as heavy as hydrogen.

The Atmosphere is composed principally of nitrogen and oxygen mixed together in the proportion of 20.93 parts of oxygen, by volume, to 79.07 parts of nitrogen, and, by weight, 23 parts of oxygen to 77 parts of nitrogen.*

Although air is a mixture and not a definite compound, it is remarkably constant in composition. Regnault found in 233 analyses of air, at different times and places, that the per cent. of oxygen by volume varied between 20.908 and 20.999. That air is a mixture is proved by: 1st, its gases are not present in the proportion of their atomic weights; 2d, an air answering to all the properties of the atmosphere, can be made by a mechanical mixture of the gases; 3d, solvents for oxygen, as an alkaline solution of pyrogallic acid, remove this gas from the air; 4th, each gas dissolves in water independently of the other, and with its own solubility; thus by expelling the air from water, by boiling, and analyzing it, we find it to correspond to that calculated from the known solubility of the two gases. (See page 74.)

The analysis of the air expelled from water shows 33 per cent. of oxygen and 67 per cent. of nitrogen; it is, therefore, much richer in oxygen than the atmosphere Owing to the rapid diffusion of the gases, the disturbances in composition due to the respiration of animals and to manufacturing processes, are soon restored. Besides the two chief gases found in the air, there are various other ingredients found in small qantities, as watery vapor, carbon dioxide, ozone, ammonia, nitric and nitrous acids, hydrocarbons, solid particles of dust, sodium chloride, vegetable germs or spores, bacteria, etc. Air in which animals are confined also contains some organic matter, exhaled from their bodies. In the neighborhood of large cities, various other substances are poured into the air from manufacturing establishments.

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* The exact amount of argon present in air is not certainly known, but is about 0.75 to 0.80 per cent. by volume. This gas is included in the nitrogen in the above figures.

The essential ingredients are oxygen, nitrogen, carbon dioxide, and watery vapor. The rest of those enumerated, may be regarded as accidental, and not essential to the life of plants and animals.

Watery Vapor.—The proportion of water vapor in the air varies considerably with the temperature and locality. The air is seldom saturated in the daytime, and contains less inland than near large bodies of water. The higher the temperature of the air the more moisture it will hold; thus, at 0° C. (32° F.), 1 cu. metre (1.3 cubic yards) is saturated by 5.4 grams (83.3 grs.) of water, and at 25° C. (77° F.), the ordinary temperature, it requires 22.5 grams (347 grs.). Or, at 77° F., one cubic yard will be saturated by 267 grains of water, and one cubic foot by about 10 grs. In reality, the air will seldom be found to contain more than 60 or 70 per cent. of this amount. When one cubic metre (1.3 cu. yds.) of an atmosphere saturated at 25° C. (77° F.), is cooled down to 0° C. (32° F.), it will deposit, as dew, rain or frost, 22.5 — 5 4 = 17.1 gms. (263.8 grs.). The temperature at which air begins to deposit its moisture, on being cooled, is called the **dew point.** The dew point will depend upon the amount of water actually present in the air. The amount of moisture is determined by passing a known volume of air through tubes containing calcium chloride, which absorbs the water. The increase in the weight of the tubes gives the weight of water. The amount of vapor in air varies from .3 to 1.6 per cent. by volume. The dampness of the air does not depend upon the amount of water it contains, but upon the degree of saturation. A cold damp air, when heated, becomes dry; hence, the necessity of supplying moisture to the heated air in our rooms in winter. A very dry air irritates the air passages, produces dryness of the skin, and malaise. A very moist atmosphere checks evaporation from the skin and lungs, raises the bodily temperature, and soon becomes oppressive. A damp air favors the growth of many varieties of disease-producing organisms, as those of cholera, typhoid fever, and probably tuberculosis.

Carbon Dioxide.—The average amount of carbon dioxide, CO_2, in country air is 4 parts in 10,000, and varies from 3 to 6 parts. It is greater near large cities and manufactories; greater during the night than the day on land, and the reverse on the ocean. Plants remove it from the air in the daytime, and the cooler water at night absorbs more than the warmer water during the day. (See Carbon Dioxide.)

Ammonia.—This exists in the air, in very minute quantities, principally in the form of carbonate, the result of the decomposition of animal and vegetable organic matters. It is especially evolved from urinals, privy vaults and horse stables. It is washed out of the air by falling rain, and is taken up from the soil by plants.

Nitric and Nitrous Acids occur in extremely minute quantities, and are produced by the direct union of oxygen and nitrogen, in the presence of watery vapor, under the influence of discharges of lightning. They exist principally in combination with ammonium.

Hydrocarbons, the principle of which is marsh gas, are frequently found in the air of cities, coal mines, wells and swampy districts. It is produced by the decomposition of vegetable matter under water, and in some industral processes.

Accidental Gases in the Air.—The gases generated in certain manufacturing processes are sometimes allowed to escape into the air. Some of these are harmless and others hurtful. Among the first class may be mentioned **carbon dioxide,** when not in too large quantities, and **ammonia.** To the second class belong **hydrogen sulphide, ammonium sulphydrate, sulphurous oxide** in large quantities, vapors of **mineral acids, carbon disulphide,** etc.

Hydrogen Sulphide, or **Sulphuretted Hydrogen,** (H_2S) is found in certain tunnels and mines, caused by the decomposition of iron pyrites. It is also found in the air of some marshes and sewers.

The symptoms produced by breathing small quantities of this gas, are those of debility and anæmia; in larger quantities, headache, vertigo, weak pulse, sweating and prostration.

Ammonium Sulphydrate, (NH_4HS), produces nearly the same symptoms as hydrogen sulphide. It occurs in the air of sewers and privy vaults. Both these substances are easily destroyed by chlorine or sulphurous oxide.

Sulphurous Oxide (S_2O), unless in considerable quantities, and in a closed room, does not seem to have any deleterious effect upon the workmen. In bleachers it sometimes produces irritation of the bronchial tubes.

Hydrochloric Acid, Nitric Acid, and **Chlorine** in considerable quantities are very irritating to the lungs and conjunctiva.

Carbon Disulphide (CS_2) produces unpleasant and deleterious effects upon workmen exposed to air containing it, as headache, giddiness, nervous depression and loss of appetite.

Suspended Matters.—A great variety of solid particles, or dust, are found in the air at all times. These consist of fragments of wood, textile fabrics, metals, etc., pollen of plants, bacteria germs, etc. These suspended particles may be regarded as impurities, and many of them are injurious to health. Workmen in various trades are seriously affected by the dust to which they are exposed ; as miners, especially of lead and coal, grinders of metal, wool sorters, rag pickers, feather dressers, etc The irritation of the dust of these and other trades may cause chronic bronchitis, emphysema, phthisis, or chronic poisoning. Germs of various kinds are believed to cause many of the contagious and malarial diseases, and may be carried some distance in the air. Some of these germs seem to be easily oxidized, while others are very persistent. The best disinfectants for their destruction are free ventilation and consequent dilution with dry air, chlorine, bromine, iodine and sulphurous oxide.

Disinfectants, Germicides,* Antiseptics, Deodorizers.—The presence of odors and organized "germs," in the air often require the use of one of the above agents. **Disinfectants** are a class of bodies which are supposed to destroy the germs, and thus prevent them from causing their specific action either upon the human body or in decomposable organic bodies or solutions.

The most efficient of these is heat. Organized germs may be filtered from the air by passing it through cotton wool ; or they may be removed by enclosing the air in a tight box or chamber, the insides of which are moistened with glycerin. (Tyndal.) Ozone, chlorine, bromine, iodine, sulphurous oxide, the chlorides of mercury, zinc, aluminium, magnesium and calcium, potassium chlorate, potassium permanganate, carbolic, boric, cresylic and sulphuric acids, thymol, menthol, camphor, etc., are among the disinfectants most used.

Antiseptics are agents which retard or entirely prevent putrefaction, or growth of microscopic organisms. While **dis-**

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* A *germicide* is an agent which has the power of killing the germs, and thus preventing their growth. A disinfectant destroys the infectious properties of septic matter, whether this be due to germs or some other agent.

infectants destroy the cause of infection, **antiseptics** prevent the development of these causes. Low temperature retards putrefaction, and is, therefore, an antiseptic agent. These two terms are frequently used interchangeably.

Asepsis is a condition of entire absence of any germs or cause of infection. **Deodorizers** are bodies used to destroy offensive odors. They may be either solid, liquid or gaseous. **Solids**—dry earth, lime, charcoal, ferrous sulphate, carbolates of calcium, sodium and magnesium. **Liquids**—solutions of plumbic nitrate (Ledoyen's fluid), zinc chloride (Burnett's fluid), potassium or sodium permanganate (Condy's fluid), a mixture of copper and zinc sulphates (Lenande's disinfectant), solutions of ferric chloride, of ferrous sulphate, hypochlorites, etc., are among the best known. **Gases**—pure air, ozone, chlorine, bromine, and sulphurous oxide are the most effective. Fumigations with tar, herbs, and various aromatic substances, only disguise the offensive odors, but do not destroy them.

The ordinary offensive odors are due to hydrogen sulphide (H_2S), ammonium sulphydrate (NS_4HS), phosphorous hydride (PH_3), and complex ammonium compounds. Chlorine, ozone, and nitrous oxide will destroy these gases by oxidation, and thus destroy the odor.

It should be remembered that these odors, in themselves, may not be in any degree injurious to health, when in small quantity, but they serve to warn us of the presence of products of putrefaction which accompany them, and which are injurious. The fact that efficient disinfection of the air can prevent the spread of the contagion of disease is well known. Chlorine and sulphurous oxide are the two agents most in use, and of these the former is very much to be preferred, but the latter is used for furnished rooms, because of its less destructive action on articles exposed to it.

It is doubtful whether organized germs in the air can be destroyed by any disinfectants, except in tightly closed rooms. The attempt to disinfect the air of rooms with the various so-called "disinfectants" of the market, is worse than useless. It engenders a feeling of security where there is none. These floating germs can certainly stand as much, and, in most cases, more than man, and therefore no room can be disinfected while it is occupied by human beings. The author has found by experiment, that most of the ordinary antiseptics, when diffused through the air of an ordinary room, are almost without action on putrefactive bacteria, unless the quantity be great enough to make the air irrespirable.

The following table shows the amount of water it is necessary to add to one part of the substance named, which barely permits the development of bacteria in meat infusions, according to M. Jalan de la Croix:—

1 Part.	Water, Parts.	1 Part.	Water, Parts.
Alcohol,	30	Oil of mustard,	5,734
Chloroform,	134	Sulphurous acid.	7,534
Borax,	107	Aluminum acetate,	7,535
Eucalyptol,	308	Salicylic acid,	7,677
Phenol (Carbolic acid),	1,002	Mercuric chloride,	8,358
Thymol,	2,229	Calcium hypochlorite,	13,092
Potass. permanganate,	3,041	Sulphuric acid,	16,782
Picric acid,	3,041	Iodine,	20,020
Borated sodium salicylate,	3,377	Bromine,	20,875
Benzoic acid,	4,020	Chlorine,	34,509

Devaine says of iodine, that 1 part to 12,000 destroys the contagion of charbon, and 1 to 10,000 of septic blood. Billroth says mercuric chloride 1 to 20,000, thymol and benzoate of sodium 1 to 2000, and benzoic acid and creasote 1 to 1000, prevent the development of bacteria. Koch says of mercuric chloride, 1 to 15,000 kills most micro-organisms, and 1 to 1000 destroys resting spores.

The results of different experimenters are so widely discordant, that we make no attempt to reconcile them. The following table represents the results of experiments with commercial disinfectants. The first column gives the per cent. of the agent necessary to kill **anthrax** and **bacillus subtilis.** The second gives the per cent. of the agent which failed to produce this result :—

List of Commercial Disinfectants (*Sternberg*).

NAME.	Per cent. in, when active in two hours.	Per cent. in, which failed in two hours.
Little's Soluble Phenyle,	2	1
Labarraque's Solution (U. S. P.),	7	5
Liquor Zinci Chloridi (Squibbs),	10	7
Feuchtwagner's Disinfectant	10	8
Labarraque's Sol. (Frerė, Paris),	15	10
Phenol Sodique,	15	10
Platt's Chlorides,	20	15
Gerondin Disinfectant	25	15
Williamson's Sanitary Fluid,	25	20
Bromo-chloralum,	25	20
Blackman's Disinfectant,	30	20
Squibb's Impure Carbolic Acid,	. .	50
Bouchardat's Disinfectant,	. .	50
Phenol Sodique (Paris),	. .	50
Listerine,	. .	50
Hypochlorite of Sodium or Calcium. Available Chlorine,	0.25	. .

Nitrogen and Hydrogen.—Ammonia—Source.—From the decomposition of animal or vegetable matter containing nitrogen, either spontaneously or by the aid of heat. First prepared by distilling camel's dung, in Libya, near the temple of Jupiter Ammon. When horns, clippings of hides, or coal are heated in closed retorts, ammonia is given off. The principal source, at present, is from the ammoniacal liquors of gas works. Coal contains about 2 per cent of nitrogen, which is mostly given off as ammonia. The ammonia liquor is treated with hydrochloric acid, and evaporated to dryness, when an impure ammonium chloride, **sal-ammoniac,** is obtained. This may be purified by recrystallization or sublimation. This salt, heated with lime (CaO) gives off its ammonia. This is conducted through a series of Woulfe bottles containing water, in which the gas dissolves, forming aqua ammonia, from which the other compounds may be prepared.

$$2NH_4Cl + CaO = 2NH_3 + H_2O + CaCl_2.$$

Properties.—Ammonia is a colorless, transparent, pungent, irrespirable gas. It does not support combustion or burn in the air, but burns with difficulty in an atmosphere of oxygen, forming water and free nitrogen. It has a strong alkaline reaction, on moistened litmus paper, which, however, is not permanent, owing to the volatility of the ammonia.

It is lighter than air. Liquefies at — 40° C. (— 40° F.); or at 10° C. (50° F.), under a pressure of 6.5 atmospheres, to a colorless liquid of specific gravity 0.76, which solidifies at — 75° C. (— 103° F.).

It is very soluble in water; one volume of water at 15° C. (59° F.) dissolves 783 volumes of the gas with the evolution of heat, forming the solution known as **aqua ammoniæ,** which may be regarded as a solution of ammonium hydroxide, NH_4–O–H in water.

This solution, on being heated, gives up most of the gas again. **Aqua ammoniæ fortior** (U. S. P.) contains 28 per cent., by weight, of the gas, and has a sp. gr. of 0.901 at 15° C. (59° F.). **Aqua ammoniæ** (U. S. P.) contains 10 per cent., by weight, and has a sp. gr. of 0.960 at 15° C. (59° F.). It is a colorless, transparent liquid, with a pungent odor, and alkaline taste and reaction. It forms, by direct union with the acids, a series of salts containing the compound radicle NH_4, called ammonium (see page 244 *et seq.*). Ammonia is volatile, and hence it is sometimes known as the **volatile alkali.** The compound of

NH_4 closely resemble those of Na and K, and will be considered with them. Strong solutions of the gas act as a caustic upon animal tissues, and are, therefore, corrosive poisons.

Composition.—This may be determined by decomposing the gas by passing a series of electric sparks through a quantity of it enclosed in an eudiometer tube over mercury. The volume increases until double the original volume is reached. By introducing a quantity of oxygen equal to ¾ that of the ammonia used, and igniting the gases by the same spark, the hydrogen and oxygen combine, and after condensing leave the nitrogen, which occupies one-half the original volume, or one-fourth the volume of the mixed hydrogen and nitrogen after the decomposition. It is thus shown to be composed of one-fourth nitrogen and three-fourths hydrogen.

We may also arrive at the same result in the following manner:—

Prepare a glass tube of about 1 cm. (⅓ in.) calibre, closed at one end; through the stopper in the open end pass a funnel tube drawn to a point and provided with a stop-cock. Fill the tube with pure dry chlorine, and insert the cork. Fill the funnel tube with strong ammonium hydroxide solution, open the stop-cock, and allow a portion of the liquid to enter the tube. The chlorine decomposes the ammonia gas, combining with its own volume of hydrogen and setting free the nitrogen in combination with it. By removing the stopper under water, the latter will rise to fill the tube, excepting that portion occupied by the nitrogen, which will be found to be one-third of the whole tube.

Now, as the chlorine combined with its own volume of hydrogen, or with the tube full, and left one-third of that volume of nitrogen, it is easy to see that the ammonia was composed of three parts by volume of hydrogen, and one part of nitrogen. Since gaseous molecules all occupy the same space, three molecules of hydrogen and one of nitrogen form two of ammonia:

$$3H_2 + N_2 = 2NH_3.$$

The compounds of ammonium with acids will be considered under the head of salts of the alkaline metals. The compound, or derived ammonias, will be considered in part IV.

Tests.—Odor. Fumes with HCl. Moistened red litmus paper is changed to blue by it. For Nessler's test, see page 144.

Nitrogen Chloride (NCl_3).—When chlorine **in excess** is made to act upon ammonia, or a solution of ammonium chloride, the chlorine at first sets free nitrogen, and forms some ammonium chloride; the excess of chlorine then acts upon the ammonium chloride, to form nitrogen chloride.

$$NH_4Cl + 3Cl_2 = NCl_3 + 4HCl.$$

Properties.—A yellow, oily liquid, insoluble in water, possessing a disagreeable, irritating odor. Sp. gr. = 1.653 It is very explosive, and, in contact with any combustible matter, explodes spontaneously. It should not be prepared in large quantities.

Nitrogen Iodide (NHI_2 or NI_3). **Preparation.**—By lightly triturating iodine in a mortar with strong ammonium hydroxide, or by pouring an alcoholic solution of iodine into strong ammonia water.

Properties.—A brownish-black solid, insoluble in water; when spread out on filter paper and dried, it explodes with the slightest touch, or by a gentle breeze; the explosion, however, is not nearly so violent as that of the chlorine compound.

Nitrogen and Oxygen.—Five oxides of nitrogen are known, whose names, graphic formulæ, and corresponding acids are as follows:—

Nitrous Oxide, ...	$N-O-N$	**Hyponitrous Acid,**	$H-O-N$
Nitric Oxide, ...	$O\equiv N--N\equiv O$		
Nitrous Anhydride, ...	$O\equiv N-O-N\equiv O$	**Nitrous Acid,**	$H-O-N\equiv O$
Nitric Peroxide, or Tetroxide, ...	$\left\{\begin{matrix}O=\\O=\end{matrix}\right.N-O-N\equiv O$		
Nitric Pentoxide, or Anhydride, . . .	$\left\{\begin{matrix}O=\\O=\end{matrix}\right.N-O-N\begin{matrix}=O\\=O\end{matrix}$	**Nitric Acid,** . .	$H-O-N\begin{matrix}=O\\=O\end{matrix}$

Nitrous Oxide, Hyponitrous Oxide, Laughing-gas. Nitrogen Monoxide. Nitrogen Protoxide (N_2O).—Discovered in 1776, by Priestly. Anæsthetic effect first discovered by Sir Humphrey Davy. First used in dentistry by Wells, of Hartford, Ct. First came into notice as an anæsthetic in 1863.

Preparation.—By gently heating ammonium nitrate in a retort similar to that represented in Fig. 46, when it decomposes into nitrous oxide and water.

$$NH_4NO_3 = N_2O + 2H_2O.$$

When prepared for anæsthetic purposes, care should be exercised to keep the temperature of the retort between 210° C. (410° F.) and 250° C. (482° F.), as below the former the decomposition does not take place, but the salt sublimes; while above the latter nitrogen dioxide and trioxide are generated. As an additional safeguard, the gas should be caused to bubble through solutions of sodium hydroxide and ferrous sulphate, to remove these higher oxides.

Properties. — A colorless, odorless, sweetish-tasting gas, slightly soluble in water, more so in alcohol. Density, 21.85. Sp. gr., 1.527. Under a pressure of 50 atmospheres at 7° C.

(45° F.) it condenses to a colorless liquid, which resumes the gaseous state as soon as the pressure is removed, the temperature sinking so low as to freeze a portion of the liquid into a white, snow-like solid. Sp. gr. of liquid, 0.908. Boiling point—88° C. (—126° F.). Freezing point about—101° C. (—150° F.). It is neutral in reaction, *i. e.*, neither acid nor alkaline It supports the combustion of bodies very much like oxygen; this is due to the fact that the heat of the burning bodies decomposes the gas, giving an atmosphere about them containing twice as much oxygen as ordinary air For anæsthetic purposes, the liquefied gas is now sold in wrought-iron cylinders, provided with a stop-cock, so that the gas can be drawn from the cylinder as needed.

Physiological Effects.—Nitrous oxide causes, when first inhaled, an exhilaration, then anæsthesia, and finally, asphyxia. It will not support the respiration of plants or animals. It seems to act partly by excluding air, and partly by its direct effect upon the nervous system. It does not enter into any chemical combination in the blood, but simply dissolves in this fluid. When mixed with oxygen, and administered under an increased pressure, the anæsthesia may be kept up for a long time with safety. Deaths from its inhalation are rare. It does not undergo decomposition in the blood. It is much used for short operations, and especially for the extraction of teeth, opening abscesses, felons, etc. Recovery is prompt and complete within a few minutes after its withdrawal. A solution in water containing five volumes of the gas has been administered internally.

Hyponitrous Acid (HNO).—This acid may be prepared by the action of hydrochloric acid on the silver salt.

$$AgNO + HCl = AgCl + HNO.$$

The potassium salt (KON) is formed by the action of sodium amalgam on potassium nitrite or nitrate; preferably the former:

$$2KONO + 2H_2 = 2KON + 2H_2O.$$

The silver salt is a yellow, almost insoluble powder.

Nitric Oxide or Nitrogen Dioxide. NO or N_2O_2.—Prepared by the action of nitric acid upon copper.

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + N_2O_2 + 4H_2O.$$

Properties.—A colorless, transparent gas, very sparingly soluble in water, more soluble in alcohol. Density 15, sp. gr. 1.039.

The density would make the molecular weight 30, and the formula NO, which is anomalous, as in this case nitrogen must be considered as a dyad. The ordinary laws of valence would make it N_2O_2. It is probable that at lower temperatures this is the proper formula, and at the higher temperature dissociation takes place, N_2O_2 splitting up into NO, as has been proven to occur in the case of N_2O_4.

By cold and pressure, the gas has been reduced to a liquid. Bodies which evolve considerable heat in burning, as phosphorus, for example, burn in this gas, first decomposing it, and then uniting with its oxygen. In contact with free oxygen, or air, it takes up this gas and is converted into N_2O_4, or N_2O_3, according to the amount of oxygen present. In both cases it gives a reddish-brown colored gas. The gas may be used as a **test** for free oxygen. It is rapidly absorbed by a solution of ferrous sulphate, to which it imparts a deep brown color. Its action on the economy is not known. It forms no corresponding acid.

Nitrous Anhydride (N_2O_3).—Prepared by the direct union of nitric oxide (N_2O_2) and oxygen, mixed in the proportion of two of the former to one of the latter. Also, by warming nitric acid with starch, or arsenious acid, and by the action of the peroxide on cold water.

$$2N_2O_4 + H_2O = N_2O_3 + 2HNO_3.$$

Properties.—A dark blue liquid, boiling at 0° C. (32° F.), with partial decomposition, into N_2O_2 and N_2O_4 which recombine on cooling. It combines directly with water, producing nitrous acid (HNO_2), which, on warming, decomposes into nitric acid and nitric oxide.

$$3HNO_2 = HNO_3 + N_2O_2 + H_2O.$$

As will be seen from the above, this oxide is very unstable.

Nitrous Acid and Nitrites.—The acid is not known in a pure state, but it exists in solution, and several of its salts are known. The nitrites are formed by heating the nitrates, when they give off a part of their oxygen. The action is rendered easier, if lead or some other oxidizable metal be added to the fusion. The nitrites are produced in nature by the oxidation of nitrogenous organic matter, accompanied by certain forms of microscopic life. Such nitrification takes place in waters polluted with organic matter, and normally in the soil. The acid then combines with bases found in the water or soil. The presence of nitrites in water, is, for this reason, looked upon as an evidence of previous contamination with nitrogenous organic matter. Further oxidation leads to the formation of nitrates in the same circumstances. The addition of a diluted mineral acid to a nitrite, sets free reddish-brown fumes. A solution of argentic nitrate forms a precipitate with cold, not too dilute, solutions of an alkaline nitrite. These two reactions distinguish these salts from the **nitrates.** The reddish fumes, above mentioned, are strong oxidizing agents, and set free iodine from potassium iodide. A solution of starch with which iodine forms a deep blue color, and a solution of potassium iodide with diluted sulphuric acid, are used as a test for nitrites in solution.

Nitrous acid and the nitrites act as reducing agents upon an acid solution of potassium permanganate, and decolorize this latter salt. The nitrites can be taken up by plants, and elaborated into their structure, and hence are valuable fertilizers

Nitrogen Peroxide, Nitrogen Tetroxide, Nitrogen Dioxide (N_2O_4).—It may be prepared by mixing equal volumes of nitric oxide and oxygen :—

$$N_2O_2 + O_2 = N_2O_4.$$

or, more easily, by heating dry plumbic nitrate in a retort, and passing the vapors into a cooled receiver, where they condense into a liquid :—

$$2Pb(NO_3)_2 = 2PbO + 2N_2O_4 + O_2.$$

Composition.—N_2O_4 appears to exist in a pure state only at temperatures below 0° C. (32° F.). The liquid is colorless at these temperatures, but at its boiling point is yellow in color, owing to partial dissociation into NO_2, which is complete at about 150° C. (302° F.).

The gas is always reddish-brown in color, due to the presence of NO_2, while N_2O_4 is colorless. The density of the gas at 26° C. (78.8° F.) (the boiling point of the liquid), is 38, and contains 20 per cent. of NO_2. On raising the temperature, the density diminishes and finally becomes constant at 150° C. (302° F.), and equals 23. This density corresponds to $NO_2 = 46$. This phenomena of dissociation is frequently noticed in determining the density of bodies at temperatures much above their boiling points. The laws of equivalence seem to hold, in these cases, only at the lower temperatures, at which dissociation does not take place; hence, the confusion that exists in the formulæ of such bodies as

$$N_2O_4 \text{ or } NO_2,\ N_2O_2 \text{ or } NO,\ Hg_2Cl_2 \text{ or } HgCl, \text{ etc.}$$

Properties.—Cold water, in small quantity, decomposes it into N_2O_3 and HNO_3, while in larger quantities and with alkaline hydroxides, it forms nitrous and nitric acids, or their salts.

The tetroxide, N_2O_4, and the dioxide NO_2, both act as strong oxidizing agents, setting iodine free from the iodides.

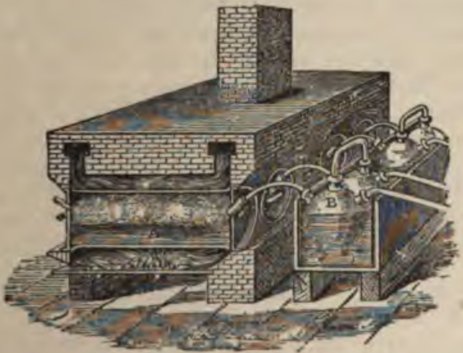
Nitric Anhydride and Acid,—N_2O_5 and HNO_3. **Nitric Anhydride** is a white crystalline solid, fusing at 30° C. (86° F.), and boiling at 47° C. (116.6° F.). Obtained by treating dry silver nitrate with chlorine, or by the removal of water from fuming nitric acid by the action of phosphoric anhydride (P_2O_5). The oxide is unstable, and has a strong affinity for water with which it forms nitric acid. It has no special use.

Nitric Acid—Aqua Fortis,—Acidum Nitricum, U. S. P. (HNO_3), is the most important of the acids of nitrogen. It does not occur free, but as nitrates widely disseminated. It is usually prepared, commercially, by the action of sulphuric acid upon potassium or sodium nitrate, in glass or cast-iron retorts.

$$NaNO_3 + H_2SO_4 = HNaSO_4 + HNO_3.$$

The arrangement of the iron retorts (A) and the stoneware condensers (B) are shown in section in Fig. 55. The sodium nitrate and an equal weight of sulphuric acid is run in through the stoppered openings at the back. The iron is protected from the acid by a lining of fire clay. When heat is applied to the retort the nitric acid distils over and condenses in the stoneware Woulfe bottle B, which is kept cooled by cold water.

Fig. 55.



It is also formed in small quantities by the passage of electric discharges through a mixture of nitrogen and oxygen. This takes place in the air by the passage of flashes of lightning, probably by the oxidizing action of the ozone generated by these phenomena. The nitrates are formed in the soil and natural waters by the oxidation of organic matter, called nitrification, and is induced by certain microscopic organisms called the nitriby ferment. In some localities the process is conducted artificially [illegible] Nitre.

The commercial acid prepared as above contains sulphuric acid, traces of iron, the lower oxides and chlorine. It is purified by redistilling with potassium nitrate, which retains the impurities and allows the pure acid to distil over.

Properties.—The pure acid is a colorless, rather heavy, fuming liquid, having a sp. gr. of 1.52, boiling at 86° C. (186.8° F.), and solidifying at —40° C. (—40° F.). The sp. gr. and boiling point of the diluted acid vary with the proportion of acid present. When strongly heated, or on exposure to light and air, the acid turns yellow and is decomposed into nitric peroxide (N_2O_4), water, and oxygen.

Nitric acid readily gives up a portion of its oxygen, and thus acts as a strong oxidizing agent, attacking and destroying vegetable and animal tissues and coloring matters. It is sometimes used as a cauterizing agent, first producing a yellow stain, then destroying the tissue. While it oxidizes most organic bodies, it enters into the composition of others, forming substitution products. Thus glycerin, cotton, sugar, etc., when treated with it, form explosive substitution products. Most metals dissolve in the acid, forming nitrates; gold and platinum are exceptions. The non-metals or negative elements are usually oxidized by it. Metallic iron dissolves readily in the dilute acid, but when plunged into the strong acid, it assumes a condition known as the **passive state**; if now it be put into dilute acid, it is not attacked by it until a piece of platinum is brought into contact with it, or by some other means the passive condition is destroyed. **Nitroso-nitric** acid is a yellow, partially decomposed acid, containing nitric peroxide (N_2O_4). **Aqua regia** is prepared by mixing together four parts of hydrochloric, and one of nitric acid; it soon assumes a yellowish-red color, and has the power to dissolve gold, platinum and other metals, with the formation of chlorides.

Fuming Nitric Acid.—A reddish-brown acid. Sp. gr. 1.525. Containing N_2O_3 or N_2O_4. Used as a powerful oxidizing agent.

Official Forms.—Acidum Nitricum.—Sp. gr. 1.414, at 15° C. (59° F.), contains 68 per cent. of HNO_3.

Acidum Nitricum Dilutum is prepared by adding 5.8 parts of distilled water to one of the above acid. Sp. gr 1.057, at 15° C. (59° F.), and contains 10 per cent. of HNO_3. Used for internal administration. Dose, ♏ 5 to 15.

Tests.—1. Add to the suspected liquid some ferrous sulphate, and pour the mixture on some strong sulphuric acid in a test tube. A black, brown, or reddish zone at the point of contact of the two liquids indicates nitric acid.

2. Heat the suspected solution with some sulphuric acid faintly colored with indigo, when, if nitric acid or a nitrate be present, the blue color will disappear.

3. The strong acid imparts a deep red color to the alkaloid brucine.

4. When heated with copper turnings, the liquid assumes a green color, and evolves reddish fumes. When the acid is in combination, a stronger acid must be added to set it free, as in test 2.

Physiological Effects.—In small quantities, well diluted, it is a stomachic tonic, and augments the secretion of urine. It seems to be mostly decomposed in the body, but a small quantity may pass into the urine as nitrates; it acts, therefore, as a oxidizing agent. The strong acid is a corrosive, violent poison, first staining the tissues and vomit, with which it comes in contact, a bright yellow color, and then corroding them. These stains will be found on the tongue and fauces in cases of poisoning by this acid. **Antidote**—milk of lime, magnesia, or other alkalies well diluted, followed by sustaining treatment.

PHOSPHORUS.

$P = 31.$

Density of vapor $= 62$. Mol. wt. $124. = P_4$. At very high temperatures $D = 31$ and Mol. wt. $= 62 = P_2$.

Occurrence.—Discovered by Brandt, in 1669, in urine; and by Gahn, in bones, in 1769. It does not occur native, but as phosphates, and in organic substances. The most common mineral is calcium phosphate, $Ca_3(PO_4)_2$, derived from the bones of prehistoric mammals.

Preparation.—Phosphorus is usually prepared from the ash of burnt bones, in which it exists as tri-calcium phosphate, $Ca_3(PO_4)_2$. The ash, by treating it with sulphuric acid, is first converted into a soluble monocalcium phosphate, sometimes called superphosphate.

$$Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_4(PO_4)_2 + 2CaSO_4.$$

The $CaH_4(PO_4)_2$ is dissolved in water, and drawn off, leaving the

$CaSO_4$ in the vat. This solution is evaporated to dryness, after adding powdered charcoal and sand, and then transferred to a retort, whose beak dips under water. The retorts are then gradually heated to a high temperature, when the $CaH_4(PO_4)_2$ is first dehydrated and converted into calcium metaphosphate, $Ca(PO_3)_2$ and water, and then undergoes reduction under the action of the carbon and sand as follows:—

$$CaH_4(PO_4)_2 = Ca(PO_3)_2 + 2H_2O.$$
$$2Ca(PO_3)_2 + 2SiO_2 + 10C = 2CaSiO_3 + 10CO + P_4.$$

The free phosphorus distils over and condenses under the water as an impure article, which is purified by redistillation, or by fusing it under water with sulphuric acid and potassium dichromate. It is then cast into sticks, in moulds.

Properties—Physical.—Phosphorus is met with in several distinct allotropic states.

The ordinary form is a translucent, waxy-looking solid, which, at ordinary temperatures, is tenacious, and about the consistency of wax; but at 0° C. (32° F.) and below, it becomes brittle. It melts at 44° C. (111° F.) under water, and boils at 290° C. (554° F.). By the action of light, it soon becomes coated with a whitish or reddish layer, probably an oxide. The sp. gr. is 1.83 at 10° C. (50° F.). It shines in the dark, and, when exposed to moist air, emits the odor of ozone. It is insoluble in water and alcohol, but soluble in ether, benzene, petroleum, and in the fixed and essential oils. The best solvent is carbon disulphide. From this solution it separates in the form of octahedral and dodecahedral crystals. When a portion of the solution is poured upon filter paper and allowed to evaporate spontaneously, it takes fire when the evaporation is complete.

Red or **Amorphous Phosphorus** is a reddish-brown amorphous powder, of sp. gr. 2.14, insoluble in carbon disulphide; it does not alter in the air, and does not show the phosphorescence in the dark. While ordinary phosphorus is very poisonous, even to workmen handling it, this variety is entirely harmless. When heated to 260° C. (500° F.), it does not melt, but gradually sublimes. The vapor is converted into the ordinary form, which takes fire in presence of air.

Red phosphorus is prepared by heating the ordinary variety for about thirty-six hours, to a temperature of from 250° C. (482° F.) to 300° C. (572° F.) in an atmosphere of hydrogen, carbon dioxide, or in an exhausted iron vessel. The mass is then washed with carbon disulphide, to remove any of the ordinary variety remaining.

Other varieties of phosphorus have been formed. The **metallic** form is prepared by heating the red variety in a sealed tube to 500° C. (932° F.) when black, metallic-looking, microscopic needles sublime into the cooler portions of the tube. The sp. gr. of this variety is 2.34, and it is less active than the red variety.

Chemical Properties.—The most characteristic property of phosphorus is its ready oxidation. If the ordinary variety be heated to 60° C. (140° F.) in contact with air, it takes fire and burns with a brilliant flame, and evolves a voluminous white cloud of phosphoric pentoxide. It may be burned under warm water, by throwing a jet of oxygen upon it.

It must be kept under water to prevent it from taking fire spontaneously. When fragments, partly covered with water, are exposed to the air, white fumes are seen to rise from them which contain ozone, hydric peroxide, and possibly ammonium nitrite (NH_4NO_2). This ozone is the cause of the odor usually detected when phosphorus is exposed to the air. The red variety does not oxidize in the air, and may be handled with impunity. Phosphorus unites readily with fluorine, chlorine, bromine and iodine, forming in each case, two compounds of the general formula PR_3 and PR_5, except in the case of iodine, which forms PI_2 and PI_3. An oxychloride of phosphorus ($POCl$) is also known. It combines with most other elements excepting carbon, nitrogen and hydrogen. It reduces some metallic salts, as copper and silver, to the metallic state.

Tests.—Its phosphorescence in the dark, either as found, or after separating it with carbon disulphide and evaporation of the latter liquid, is used as a test. It imparts a green color to the hydrogen flame, when this gas is conducted through a solution containing it before being burned.

Physiological Action.—Owing to the ready inflammability of the ordinary variety, deep burns are liable to occur from careless handling, which are more serious and difficult to heal than burns from other combustibles. When taken internally, phosphorus is a very poisonous substance. Cases of poisoning from "ratsbane" or "rat poison" containing it, are not infrequent.

The symptoms of acute poisoning are a garlicky odor and taste in the mouth, heat and burning in the stomach, vomiting of a dark-colored matter, which is phosphorescent when shaken in the dark. Weak pulse, low temperature, cold extremities, dilated pupils, and a clear mind are usually seen. Death occurs in from 2 to 12 days. The average time is about 3 to 4 days.

These symptoms may make their appearance in an hour after the poison is taken, or after 3 or 4 days.

The poisonous dose varies. $\frac{1}{50}$ to $\frac{1}{8}$ of a grain has produced death.

Antidotes. There is no chemical antidote. Emetics, or the stomach pump are the best early treatment; then, mucilaginous drinks, with lime or magnesia, or oil of turpentine. The old oil is best; but no other oils should be given, as they dissolve the phosphorus and favor absorption. Recovery is rare.

Chronic poisoning of workmen in match factories frequently occurs; the symptoms are fatigue, pains in stomach and bowels, with diarrhœa, carious teeth, swollen and inflamed gums, and finally necrosis of the jaws, usually the lower. Fatty degeneration of the liver, kidneys, heart and other muscles, and destruction of the red corpuscles, are also noticed.

These evils are now remedied by using **red phosphorus** in making matches, as it is not poisonous.

Official Preparations:—Oleum Phosphoratum.—A 1 per cent. solution of phosphorus in sweet almond oil.

Pilulæ Phosphori.—These pills contain 0.0006 gm. ($\frac{1}{100}$ grain) of phosphorus, each, and are coated with balsam of tolu.

Spiritus Phosphori.—Spirit or Tincture of Phosphorus. This is a solution of phosphorus in absolute alcohol, made by distillation, and containing 1.2 gm. in 1000 c.c.; it is used for making **Elixir Phosphori.** This elixir contains 210 c.c. of the tincture and 550 c.c. of glycerin, to the litre.

Phosphorus and Hydrogen—Phosphoretted Hydrogen.—Phosphin.—There are three hydrides of phosphorus known, which are all formed together by boiling phosphorus with strong potash or soda lye, or with milk of lime. They appear as a gaseous mixture, which takes fire spontaneously on coming to the air. When the beak of the retort in which it is prepared dips under water, a precaution always to be taken, each bubble ignites on coming to the surface, producing beautiful white rings of P_2O_5. This inflammable gas, composed mostly of PH_3, is found on examination to contain also a liquid compound (P_2H_4), which is highly inflammable on exposure to air, while the gas (PH_3) is not. This yellow volatile liquid, on standing in sunlight, deposits a yellow solid (P_4H_2).

Phosphin (PH_3) is colorless, sparingly soluble in water, and has a strong alliaceous odor.

The impure gas is formed during the putrefactive decomposition of organic substances containing phosphorus, especially under water, and takes fire spontaneously on rising to the surface, producing the **ignis fatuus** or "Will o' the wisp" sometimes seen in marshy places. The gas is very poisonous, even in small quantities. The blood, after deaths caused by it, is found to be dark colored, with a violet tinge, and has lost the power of absorbing oxygen. It poisons, therefore, by its reducing action on the blood. Its density is 17, and its sp. gr. 1.134.

Phosphin resembles, in some respects, the corresponding compound of nitrogen, (NH_3). It unites directly with HBr and HI to form **phosphonium bromide,** (PH_4Br), **and iodide,** (PH_4I), corresponding with the ammonium compounds, NH_4Br and NH_4I.

Phosphorus and the Halogens.—Phosphorus forms three compounds with chlorine. **Phosphorus trichloride,** PCl_3, is a colorless fuming liquid, boiling at 74° C. (165.2° F.), sp. gr. 1.64, and prepared by direct union of the elements. It is much used as a reagent in organic chemistry.

Phosphorus Pentachloride (PCl_5), is a yellowish-white, crystalline solid fuming in the air, and subliming without fusion, when heated. It is prepared by treating PCl_3 with an excess of chlorine, and is used as a reagent in organic chemistry.

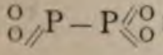
Phosphorus Oxychloride ($POCl_3$), is formed by the action of a limited quantity of water on the pentachloride. It is a colorless liquid with a pungent odor, and a sp. gr. of 1.7. Boils at 110° C. (230° F.). Phosphorus unites directly with bromine, giving a tribromide and pentabromide; and with iodine, giving two crystalline solid compounds, PI_3 and P_2I_4; and with fluorine, PF_3 and PF_5. These latter compounds, as well as those of phosphorus with sulphur, of which there are six known, are of no interest to the medical student.

Phosphorus and Oxygen.—The following oxides and acids are known:—

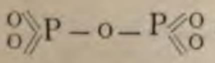
P_4O Phosphorus suboxide.

P_2O, $P-O-P$ Phosphorus monoxide $+ 3H_2O = 2H_3PO_2$. Hypophosphorous acid.

P_2O_3, $O=P-O-P=O$ Phosphorous trioxide $+ 3H_2O = 2H_3PO_3$. Phosphorous acid.

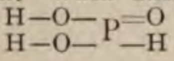
P_2O_4,  Phosphorus tetroxide.

$$\begin{matrix}O\\O\end{matrix}\!/\!\!/P-P\begin{matrix}/\!\!/O\\ \backslash\!\!\backslash O\end{matrix}$$

P_2O_5,  Phosphorus pentoxide

$$\begin{matrix}O\\O\end{matrix}\!\!\gg\!P-O-P\begin{matrix}/\!\!/O\\ \backslash\!\!\backslash O\end{matrix}\quad\begin{cases}+ 3H_2O = 2H_3PO_4 \\ \text{Orthophosphoric acid.} \\ + 2H_2O = H_4P_2O_7 \\ \text{Pyrophosphoric acid.} \\ + H_2O = 2HPO_3 \\ \text{Metaphosphoric acid.}\end{cases}$$

Phosphorous Oxide, Phosphorous Trioxide (P_2O_3). This compound is formed by the slow oxidation of phosphorus in dry air. When dissolved in water it forms **phosphorous acid,**



$\begin{matrix} H-O- \\ H-O- \end{matrix} P \begin{matrix} =O \\ -H \end{matrix}$

$$P_2O_3 + 3H_2O = 2H_3PO_3 \text{ or } 2H_2PHO_3.$$

Phosphorous Acid is a colorless liquid, which is easily oxidized to phosphoric acid by absorbing oxygen from the air. It is a dibasic acid. Its salts are known as phosphites.

Na_2PHO_3	Sodium phosphite.
K_2PHO_3	Potassium phosphite.

Tests.—1. With $HgCl_2$ it gives a white ppt. consisting of Hg_2Cl_2.

2. With $AgNO_3$ it gives a black ppt. of metallic silver.

Phosphoric Oxide, Phosphorus Pentoxide (P_2O_5).—This is formed by the rapid burning of phosphorus in the air, and rises as a voluminous white cloud. It has a powerful affinity for water, with which it combines with a hissing noise, forming metaphosphoric acid; this when heated with more water is converted into the orthophosphoric acid.

$$P_2O_5 + H_2O = 2HPO_3.$$
$$2HPO_3 + 2H_2O = 2H_3PO_4.$$

Orthophosphoric Acid, or **Common Phosphoric Acid,** (H_3PO_4), is the most important acid of Phosphorus. It is readily prepared by boiling phosphorus with diluted nitric acid, and evaporating the solution to a syrupy consistency.

A very strong nitric acid should not be used, because the oxidation would then be so rapid that an explosion might occur.

$$3P_2 + 10HNO_3 + 4H_2O = 6H_3PO_4 + 5N_2O_2.$$

It may also be made by decomposing phosphates with sulphuric acid. It is a tribasic acid forming three series of salts, namely:

1. **Normal salts.**

Na_3PO_4	Trisodium phosphate.
$Ca_3(PO_4)_2$	Tricalcium phosphate.

2. **Acid salts.**

A.	Na_2HPO_3	Disodium-hydrogen phosphate.
	$Ca_2H_2(PO_4)_2$	Dicalcium-hydrogen phosphate.
B.	NaH_2PO_4	Sodium-dihydrogen phosphate.
	$CaH_4(PO_4)_2$	Mono-calcium-tetrahydrogen phosphate.

(A) have a neutral, and (B) an acid reaction.

3. Double salts.

NH_4MgPO_4	Ammonium-magnesium phosphate.
$KBaPO_4$	Potassium-barium phosphate.

Acidum Phosphoricum U. S. P., is a colorless, odorless, non-fuming, strongly acid liquid, containing not less than 85 per cent. of absolute ortho-phosphoric acid. Sp. gr. 1.710 at 15° C. (59° F.). It is miscible in all proportions with water and alcohol. When heated to 200° C. (392° F.) it loses water, and is gradually converted into pyrophosphoric acid. At a higher temperature it is converted into metaphosphoric acid, which volatilizes in dense fumes, and condense into a transparent mass called **glacial phosphoric acid.**

$$2H_3PO_4 - H_2O = H_4P_2O_7 \text{ Pyrophosphoric acid.}$$
$$2H_3PO_4 - 2H_2O = 2HPO_3 \text{ Glacial, or metaphosphoric acid.}$$

Acidum Phosphoricum Dilutum, U. S. P., contains 10 per cent. of absolute H_3PO_4. Sp. gr. is 1.057 at 15° C. (59° F.).

Tests:

1. Add a slight excess of NH_4OH, then a solution of NH_4Cl, and some $MgSO_4$ solution. A white crystalline ppt. of ammonium-magnesium phosphate is produced.

$$H_3PO_4 + MgSO_4 + 3NH_4OH = NH_4MgPO_4 + (NH_4)_2SO_4 + 3H_2O.$$

2. If this ppt. be dissolved in dilute acetic acid, and a solution of $AgNo_3$ added, a yellow ppt. of silver phosphate is produced.

3. If a solution of ammonium molybdate in dilute HNO_3 be added to phosphoric acid, or a phosphate, and heat applied, a yellow ppt. of phospho-molybdate of ammonium is produced. The ppt. is readily soluble in ammonia water. This is a very delicate test.

Pyrophosphoric Acid.—When phosphoric acid is heated to about 200° C. (392° F.), two molecules lose one molecule of water, and then unite to form a doubly condensed molecule, which is called pyrophosphoric acid. This is a tetrabasic acid, $H_4P_2O_7$, and forms salts called pyrophosphates. Sodium pyrophosphate has the formula $Na_4P_2O_7$.

Tests.—1. It gives a **white** ppt. with ammonio-nitrate of silver. The ortho-acid gives a yellow ppt.

2. It is not pptd. by ammonium molybdate, and does not coagulate albumin.

Metaphosphoric Acid, HPO_3 (Glacial Phosphoric Acid).—When pyrophosphoric acid is heated almost to redness, metaphosphoric acid is produced as a white, glassy, colorless solid. It is usually prepared by heating ammonium phosphate to a red heat.

$$(NH_4)_3PO_4 = 3NH_3 + H_2O + HPO_3.$$

Metaphosphoric acid is monobasic, and forms salts called metaphosphates. $NaPO_3$ is metaphosphate of sodium.

Tests.—1. It gives a white ppt. with ammonio-nitrate of silver.

2. It coagulates albumin, while pyro- and ortho-phosphoric acids do not.

3. It is not pptd. by $MgSO_4$, in the presence of NH_4OH and NH_4Cl, as the ortho-acid is.

Meta- and pyrophosphoric acids and their salts, when taken internally, are said to have a decided inhibitory action upon the motor ganglia of the heart, and may even cause its cessation and death when given in too large quantities.

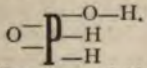
Hypophosphorous Acid (H_3PO_2).—When ordinary phosphorus is boiled with a solution of sodium, potassium, barium, or calcium hydroxide, phosphorus hydride escapes, and there is formed in the solution a hypophosphite of the metal present. The acid may be prepared from the barium salt by treatment with enough diluted sulphuric acid to precipitate the barium as sulphate. The filtered solution is then to be concentrated under the air pump, as heat decomposes it. The acid thus prepared, is a colorless, syrupy, strongly acid liquid; it is unstable in the air, gradually changing into phosphorous and phosphoric acids. The acid is of little importance, but several of its salts are used in medicine. They are generally administered in the form of syrup. They have a strong reducing action on many metallic salts, and this should be remembered in prescribing them. **Mercuric chloride** is reduced to **metallic mercury** by the alkaline **hypophosphites**, and **ferric** to **ferrous salts.**

Acidum Hypophosphorosum Dilutum, U. S. P., is a colorless, odorless liquid, miscible in all proportions with water. It should contain 10 per cent. of absolute hypophosphorous acid, H_3PO_2 or HPH_2O_2.

When subjected to high temperatures, it breaks up into PH_3 and H_3PO_4, the PH_3 igniting on contact with the air.

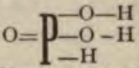
Tests.—1. Silver nitrate gives a black precipitate of metallic silver. 2. When gently heated with $CuSO_4$ solution, a yellow precipitate of hydride of copper falls, which rapidly turns reddish-brown.

Hypophosphorous, as well as phosphorous acid, is peculiar in its composition. While there are three atoms of hydrogen in the molecules of both acids, but one in the first and two in the second are basic, *i. e.*, that can be replaced by a basic radical or metallic atom. In these two acids the phosphorus is pentad, as in phosphoric acid; and in the former, two non-basic hydrogen atoms are believed to be united directly to the phosphorus, while the basic hydrogen atom is linked to it by an oxygen atom, thus:—



$$O{=}P\begin{array}{l}-O-H.\\-H\\-H\end{array}$$

Hypophorous Acid.



$$O{=}P\begin{array}{l}-O-H\\-O-H\\-H\end{array}$$

Phosphorous Acid.

ARSENIC.

As = 75.

Occurrence.—Arsenic occurs native and in the form of arsenides, the sulphides, **orpiment** and **realgar**, and as arsenical pyrites or **mispickel.** Besides occurring in these minerals in considerable quantities, it is contained in small quantities in a great number of other minerals, and even in organic substances. The sulphides, and even the element, were known to the Ancients.

Preparation.—It is usually obtained in the form of the oxide by calcining mispickel, and condensing the white volatilized As_2O_3; this oxide is then strongly heated in a retort with charcoal, when the element distils over. Although this is the method most used, it may be obtained from other minerals containing it.

Properties.—A brittle, steel-gray, crystalline solid, possessing a metallic lustre, and a sp. gr. of 5.75. It also exists as an amorphous, lustreless, black mass, easily pulverized, and having a sp. gr. of 4.71. When heated out of contact with air, under ordinary pressures, it sublimes at 180° C. (356° F.) without previous fusion; but under strong pressure it fuses. Its vapor has a yellow color and a density of 150; its molecular weight is, therefore, 300, and its molecular formula As_4. At a white heat its density is 75, and molecular formula As_2. In dry air it is permanent; but when heated, it burns with a bluish flame, emitting the odor of garlic, and white fumes of arsenious oxide (As_2O_3). It combines directly with many of the elements, both metallic and non-metallic, as chlorine, bromine, iodine, copper, iron, etc., yielding arsenides. The metallic arsenides resemble alloys. It combines readily with **nascent hydrogen,** which takes it from any of its compounds. Nitric and sulphuric acids are decomposed by it, without forming salts. It is oxidized by boiling solutions of caustic potash, forming potassium arsenite and arsenide.

Arsenic is used in pyrotechny, in the manufacture of fly poison (under the name of cobalt), in shot and in certain pigments.

Arsenic and Hydrogen.—One arsenide of hydrogen is known, AsH_3.

Hydrogen Arsenide, Arseniuretted Hydrogen, or **Arsin, AsH_3,** is of great practical interest to the toxicologist, as it enters into some of the most delicate tests for the detection of the element. It may be prepared by a number of reactions, the most common of which are the following:—

1st. By decomposing the metallic arsenides with hydrochloric acid.

2d. By the action of nascent hydrogen upon arsenical compounds. This may be generated in the hot solution by the action of caustic potash, or by dilute sulphuric acid upon metallic zinc.

3d. By the reducing action of moist organic matter upon compounds of arsenic.

It is a colorless gas, with a strong garlic odor, combustible in air, burning with a bluish-white flame, and emitting white fumes of As_2O_3; a cold surface pressed down upon this flame receives a black stain of arsenic. When passed through a tube heated to a dull-red heat, it is decomposed into hydrogen and arsenic, which last deposits in the cooler part of the tube as a metallic mirror. (See Marsh's Test, p. 191.)

The gas is readily decomposed by oxidizing agents, and the alkaline hydroxides. It is exceedingly poisonous.

Arsenic and the Halogen Elements.—Arsenic forms one compound with each of this group of elements, with the general formula $As\ R_3$, in which R stands for a halogen atom.

The tri-fluoride and the tri-chloride are liquids, the first boiling at 63° C. (145.4° F.) and the second at 134° C. (273° F.). They are formed when a fluoride or chloride is heated with arsenic trioxide and sulphuric acid.

The tri-iodide and tri-bromide of arsenic are obtained by direct union of the elements. They are both solids. The tri-iodide is official, as **Arseni Iodidum,** AsI_3. It occurs as glossy, orange-red, crystalline masses or scales. It has an iodine-like odor, and gradually loses iodine upon exposure to light and air. It is soluble in about 7 parts of water, and in 30 parts of alcohol. The aqueous solution gradually decomposes into arsenous and hydriodic acids. It is used in the preparation of **Liquor Arseni et Hydrargyri Iodidi** (Donovan's Solution) U. S. P. This solution contains one per cent. each of AsI_3 and HgI_2.

Arsenic and Sulphur.—There are at least three well-known compounds of arsenic and sulphur, As_2S_3, As_2S_5 and As_2S_2.

Arsenous sulphide (As_2S_3) occurs native as **orpiment**, in the form of gold-yellow, crystalline masses It may be prepared artificially by precipitating arsenous acid or its salts with hydric sulphide, or by heating together sulphur and arsenous oxide (As_2O_3). It is lemon-yellow in color, soluble in the alkaline hydroxides, and in yellow ammonium sulphide, but insoluble in water and dilute acids.

Arsenic Pentasulphide (As_2S_5) is also a bright yellow powder, but is of no special interest.

Arsenic Disulphide (As_2S_2), occurs native, as **realgar**, in the form of orange-red crystalline masses of sp. gr. 3.5. Realgar and orpiment are used as pigments.

Oxides and acids of Arsenic.—Arsenic forms two oxides with corresponding acids: —

As_2O_3 **Arsenous Oxide, or Anhydride.**	H_3AsO_3 **Arsenous Acid.**
As_2O_5 **Arsenic Oxide, or Anhydride.**	H_3AsO_4 **Arsenic Acid.**

Arsenous Oxide (As_2O_3) is the most important of the compounds of arsenic. It occurs in nature as arsenic "bloom." It is obtained artificially as a side product in roasting ores of other metals containing arsenic, when it volatilizes and is condensed in large chambers as a white powder. It is purified by resublimation, in iron retorts, and is obtained in the form of a white powder or glassy-looking solid, of a sp. gr. of 3.69.

Properties.—As ordinarily met with, "white arsenic" is a white, somewhat gritty powder, which under the microscope is seen to be made up of more or less regular octahedral crystals When the vapor is rapidly cooled, the crystals take the form of rhombic prisms, and it is, therefore, **dimorphous.** When heated, it sublimes without fusing, at about 218° C. (424° F.). When heated in sealed tubes, it melts into a vitreous mass. The density of the vapor is 198, corresponding to the formula As_4O_6, which is probably the formula of the vitreous variety, while that of the octahedral variety is As_2O_3. It is soluble with difficulty in water, forming a sweetish, metallic, and nauseous-tasting, poisonous solution of arsenous acid (q. v.). It is also soluble, with decomposition, in hydrochloric acid and alkaline solutions, the arsenic atoms playing the basic rôle in the former, and the acid rôle in the latter. Nascent hydrogen reduces the oxide, and converts it into arsin (AsH_3), while oxidizing agents convert it into arsenic acid.

Arsenous Acid (H_3AsO_3), is formed by dissolving As_2O_3 in water. A solution of the acid in dilute hydrochloric acid is official under the name of **Liquor Acidi Arsenosi,** containing 1 per cent. of As_2O_3. It forms a series of salts called arsenites. **Potassium arsenite** is official, as **Fowler's solution,** or **Liq. Potass. Arsenitis.**

Scheele's green is an arsenite of copper, used as a pigment. **Paris green** is a mixture of acetate and arsenite of copper.

Arsenic Oxide (As_2O_5), is a white, amorphous, deliquescent solid, dissolving in water to produce **arsenic acid.**

$$As_2O_5 + 3H_2O = 2H_3AsO_4.$$

Arsenic acid is usually prepared by warming arsenous acid with nitric acid, when the As_2O_3 is oxidized at the expense of the nitric acid. On evaporating, the solution yields needle-shaped crystals of H_3AsO_4. The aqueous solution is strongly acid. On heating the crystals of arsenic acid, both the pyro-arsenic and meta-arsenic acids are produced, corresponding to the similar acids of phosphorus. But one salt of this acid is official, Sodium Arsenate, $Na_2HAsO_4 \cdot 7H_2O$; also a one per cent. solution of this salt, as **Liquor Sodii Arsenatis.**

Arsenic Poisoning — Toxicology.— From the earliest history of arsenic, it has been used as a poison for criminal purposes.

While every physician should not undertake the analysis in cases of suspected poisoning by this agent, a knowledge of the outlines of the chemist's methods of analysis, etc., will teach the physician to prepare the way for him. Moreover, a few preliminary tests by the physician may frequently save much unnecessary litigation and expense in suspected cases. Other reasons might be given why every physician should have some knowledge of toxicological science, that care may be taken to punish the guilty and protect the innocent. The attending physician is often responsible for the connection of the links of evidence. All compounds of arsenic are poisonous, and the poison usually enters the system by the mouth, although it has been absorbed by the skin, mucous membranes, or abraded surfaces, in sufficient quantities to produce poisonous results, especially chronic poisoning.

Colored wall paper, colored toys, confectionery, and certain anilin dyes used in fabrics, may give rise to accidental poisoning.

The Physician's duty in cases of poisoning may be briefly stated us follows: In case foul play is suspected, do not fail to make careful notes, at the time, as to dates, symptoms and circumstances, or facts leading to suspicion.

The physician should collect and preserve the urine, fæces, vomit, and the suspected vehicle of the poison, and place them under seal, or lock and key. He should test some one or all of these, to satisfy himself as to the truth or falsity of his suspicion. As little publicity as possible should be given to matters of fact or of opinion at the time. Be not too ready to express your opinion upon the origin of the poison, in cases of this kind, lest you jeopardize the reputation of your patient or others. Whether a fatal termination is expected or not, it is wise to take these precautions.

In case of fatal termination, notify the prosecuting officer, or coroner, of your suspicion, and immediately request an autopsy; but remember that you are not released from your responsibility in the case by so doing, nor are you at liberty to tell all you know, until you are summoned to do so on the witness-stand.

Before you attend the autopsy, read carefully, and refresh your memory upon the directions for making post-mortem examinations, and on the post-mortem appearances in cases of poisoning, whether you are to make the examination yourself or not. If possible, see that the chemist who is to make the analysis is present at the autopsy. (See Woodman and Tidy, "Forensic Medicine.") The entire intestinal canal, at least one-half of the liver, the spleen one kidney, the brain, and any urine remaining in the bladder, should be saved; the brain and the entire intestinal canal, ligatured at both ends of the stomach and left unopened, are to be preserved in separate jars, while the other organs may be placed in a separate jar. These jars must be new and clean, and closed with new corks or glass—not with metal caps. They are then to be closed with a seal, with some peculiar stamp upon it, so that they cannot be opened without detection. They must not be intrusted to a servant or any irresponsible person, but turned over as soon as possible to the chemist, to the prosecuting officer, or coroner. Notes to be admitted on the witness-stand, must be the original; not a copy of those taken at the time to which they refer.

Symptoms of Arsenical Poisoning.—The symptoms are those of an intense irritant. There is usually marked "fire-burning" pain in the epigastrium, increased by pressure. Violent vomiting, tenesmus, burning pains at the anus, and painful cramps in the legs are usually present. Intense thirst, dry, hot skin, severe headache, small, rapid pulse, anxious, pinched countenance, the eyes suffused and smarting, tongue dry and furred, photophobia, great restlessness, nervous twitchings, with a perfectly clear mind, are symptoms usually to be expected. The urine is diminished, with frequent and painful micturition. These symptoms may end in convulsions, tetanus, collapse, or coma and death. Minimum fatal dose, from 1.5 to 2 5 grains. Chronic arsenical poisoning is usually attended by conjunctival inflammation, irritation of the skin with a vesicular, or nettle-rash eruption, similar to that of scarlet fever. Irritation of the stomach and bowels, exfoliation of the cuticle of the skin and tongue, and falling of the hair, have been noticed. Local paralyses, preceded by numbness, or tingling of the toes and fingers, and marked nervous disorders, are of common occurrence.

Treatment.—Remove any unabsorbed poison from the stomach by emetics or with the stomach pump, or better, by thorough irrigation with the stomach tube.

The best **antidote** is freshly precipitated ferric or magnesium hydroxide, or a solution of **dialyzed iron**. The solution of **dialyzed iron**, now found in the shops, may be used instead of the above, and may be given in teaspoonful doses at short intervals. This forms an insoluble compound with the arsenous acid, and thus prevents further absorption.

There are two official antidotes. 1. Freshly prepared ferric hydroxide. This is made by adding ammonia water to a solution of ferric sulphate, thoroughly washing the precipitate with water, to remove the ammonia, which is a strong caustic, and suspending the precipitate in water.

2. **Ferri Oxidum Hydratum cum Magnesia.** It is directed that a solution of ferric sulphate and a mixture of magnesia and water be kept on hand, and when wanted, the two poured together and shaken up. Ferric hydroxide and magnesium sulphate are formed. This mixture has the advantage of being free from ammonia, while the presence of magnesium sulphate is an additional advantage.

The symptoms caused by the absorbed poison are to be treated as they arise.

Toxicology.—There have been devised a large number of tests for the detection and identification of arsenic. Some of these are easy of application, while others will be used only by the chemist. We can only give the outline of these tests, and leave the student to consult special works for details. The analysis after death, in cases of suspected poisoning, should not be undertaken by the physician, nor even by a chemist, unless he has a well-equipped laboratory, in which he can conduct the analysis from beginning to end, alone, and without interruption. During the life of the patient, the physician should be able to test the urine, fæces, suspected articles of diet, medicines, etc., for the presence or absence of arsenic. For this purpose he may use Reinsch's or Marsh's test, but it must be understood that neither of these tests alone, when performed as about to be described, is to be relied upon as positively certain.

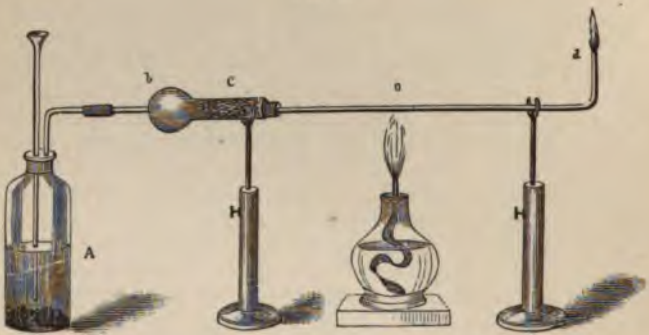
Reinsch's test may be conducted as follows:—

To a portion of the urine or other suspected liquid, add about one-sixth its volume of pure hydrochloric acid and some strips of pure copper foil, and boil the solution. If arsenic be present, a steel-gray or bluish deposit will be formed on the surface of the copper. This deposit is not positive proof, however, as antimony, bismuth and mercury may give similar deposits; it is, therefore, necessary to apply tests to this deposit, in order to determine its identity. For this purpose the copper is removed, washed in water, dried between folds of filter paper, and placed in a clean, dry, wide test tube, and heated to a dull-red heat, taking care to heat only that portion of the tube containing the copper. The tube may then be broken and the inner side of the fragments examined with a microscope, for octahedral crystals of arsenous oxide. The copper and the acid used must be shown to give no stain on prolonged boiling with distilled water. This blank experiment must always be performed.

Marsh's Test may be conducted as follows:—Although the indications afforded by it are not conclusive in the presence of organic matters, it should always be used to confirm Reinsch's test. Into a flask holding about 150 c. c. (f℥v), introduce some pieces of zinc free from arsenic and antimony; then pour over these some water acidulated with sulphuric acid; close the flask with a cork containing a funnel tube, and a delivery tube drawn to a fine point. It is best to introduce a bulb-tube, containing a pledget of cotton, arranged as at (*c*), Fig. 56. After allowing the generation of hydrogen to go on for a considerable time, to expel the air from the upper part of the flask, say half an hour, light the gas at the open end of the delivery tube, and press a cold porcelain surface down upon the flame. If the materials used are free from arsenic and antimony, there will be no black stain produced on the porcelain.

Having determined that the apparatus and materials are free from arsenic, put out the flame and pour the suspected fluid through the funnel tube, so as to admit little or no air with it into the flask. Now ignite the gas and test the flame again with the cold porcelain surface. A brilliant black or brown stain, soluble in a solution of chlorinated soda, is probably arsenic. Moisten one of these spots with nitric acid, when it should disappear; evaporate the acid over a lamp, moisten the spot with water, and hold the dish over a vessel containing sulphuretted hydrogen, prepared by the action of sulphuric or hydrochloric acid upon sodium or potassium sulphide. If the stain was due to arsenic, the spot will turn lemon-yellow. The antimony mirror is insoluble in chlorinated soda (Labarraque's solution) and after treatment as above gives an orange stain. Now soften the glass, bend the delivery tube downward and let it dip into a solution

FIG. 56.



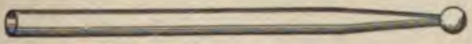
of $AgNO_3$; after an hour, pour some very weak solution of NH_4OH upon the surface of the $AgNO_3$ solution. Yellow precipitate at line of separation of the two liquids, shows the presence of arsenic. If the substance to be tested is a solid, a small portion of it may be thrown upon a glowing charcoal, when arsenic, if present, will give an odor resembling garlic. These tests will be sufficient to enable the physician to decide upon the presence of arsenic, during the life of the patient, and guide him in his treatment and behavior.

Fleitmann's Test.—Heat to boiling in a test tube, a strong solution of potassium hydroxide, in which some pieces of zinc or alluminum have been placed. Add a drop or two of the suspected solution, spread a cap of filtering paper over the mouth of the tube, and moisten it with a little nitrate of silver solution. A brown or black stain of metallic silver will appear upon the paper, if arsenic is present. The arsenous oxide is decomposed, the nascent hydrogen combines with the arsenic and forms arsin AsH_3, which reacts with the silver nitrate, reducing it to metallic silver. This test is very valuable, enabling the analyist to distinguish between arsenic and antimony, which latter does not give this reaction.

Sulphuretted hydrogen H_2S, passed into an acidulated solution containing arsenous acid, throws down a lemon-yellow precipitate, consisting of As_2S_3, which dissolves in ammonia water, and is reprecipitated by acids.

Solid arsenous oxide is mixed with some powdered charcoal and dry potassium carbonate, and placed in the bottom of a very narrow test tube, or, better, a glass tube, drawn out, and having a bulb at one end, (Fig. 57), and heated. The arsenous oxide is reduced, and metallic arsenic is deposited in the form of a ring on the cooler part of the tube.

FIG. 57.



The lower part of the tube may now be broken off, and the arsenic mirror heated; there being free access of air, the arsenic is oxidized and deposited in the upper part of the tube, in the form of octahedral crystals of arsenous oxide.

Ammonio-nitrate of silver gives a lemon-yellow precipitate, with arsenous acid solutions, of arsenite of silver, Ag_3AsO_3. It gives a brown precipitate, Ag_3AsO_4, with arsenic acid.

Ammonio-sulphate of copper gives a grass-green precipitate of arsenite of copper, also called Scheele's green, $CuHAsO_3$, with solutions of arsenous acid.

Bettendorff's Test.—Add a freshly prepared solution of stannous chloride to any arsenic compound, dissolved in strong hydrochloric acid, place in the mixture a small piece of tin foil, and apply heat; a brown color or grayish-brown precipitate is formed, according to the amount of arsenic present.

Gutzeit's Test.—Place in a test tube about 1 gram of pure zinc, and add about 5 c. c. of diluted (about 6 per cent.) sulphuric acid, then add about 1 c. c. of the solution to be tested, which should not be alkaline. Now fix a plug of cotton, moistened with lead acetate solution, in the test tube not far from the top, and fasten over the mouth of the tube a cap made of three thicknesses of filter paper, and apply a drop or two of strong solution of silver nitrate to the upper one, and place the tube in a dark box and allow it to remain for some time. If arsenic is present in the solution, a bright yellow stain will appear upon the filter paper, which upon the addition of water becomes black or brown. Antimony when subjected to the above test, gives a dark color at once, without showing a previous yellow color. The zinc and the sulphuric acid should be tested before applying the above, to make sure that they contain no arsenic.

The chemist who undertakes the analysis, in cases of supposed poisoning, has no easy task. He must not confine his tests to any one poison. Poisons are generally divided into two groups, **inorganic** and **organic.** The limits of this work will not allow us to describe the details of procedure for the chemist, who will consult special works on toxicology.

In searching for mineral poisons, the organic matters must first be destroyed or separated by dialysis. For the latter process, see page 75.

For the destruction of organic matter, two methods may be used. The solid matter—the stomach, and other organs—are to be cut in fine pieces and placed in a new porcelain dish, mixed with hydrochloric acid, and heated over a water bath. Small quantities of pure potassium chlorate are put in, from time to time, and stirred until the organic matter is destroyed. Or, sulphuric and nitric acids are used to thoroughly char the organic matter, and the whole diluted with water and filtered. The metals, except lead and barium, pass into the filtrate, and can be detected by either of the methods given above, or by other methods. These solutions may be evaporated to expel chlorine, or HNO_3, and treated with hydrosulphuric acid gas from 24 to 48 hours, when copper, lead, bismuth and mercury give black or brown precipitates; arsenic, cadmium and sometimes tin give a yellow, and antimony an orange precipitate. In searching for arsenic, the yellow precipitate obtained is separated from the liquid by filtration. A portion of this is to be preserved in a sealed glass tube. The remainder is oxidized with nitric acid, fused with sodium carbonate and nitrate, and the sodium arsenate thus formed made to yield silver and copper arsenates; the former a reddish-brown, and the latter a green precipitate. Other portions are converted into the octahedral crystals of trioxide, into the metallic state, etc., the object being to present the poison in court in as many different states as possible, so as to avoid the possibility of doubt in the minds of the jury. If the yellow sulphide, soluble in ammonia, the black metal (so called), the octahedral crystals, the mirrors with the above-mentioned properties, the coated copper obtained by Reinsch's test, the black deposit from silver nitrate, with arsenite in the filtrate, from Marsh's test, the arsenite and arsenate of silver, and arsenite of copper, etc., etc., are obtained, with proper precautions, there is no room for doubt that the substance is really arsenic.

For further directions on this subject, the student is referred to Taylor on Poisons, or Woodman and Tidy on Forensic Medicine and Toxicology, or some other similar work.

ANTIMONY.

(**Stibium.**)

$Sb = 119.6.$

Sp. gr. 6.71. Melting point 450° C. (842° F.).

Occurrence and Preparation.—Antimony occurs native; but the principal source is the trisulphide, Sb_2S_3, called **stibnite.** It occurs in a number of other ores as sulphide, or oxide.

The element is easily obtained by roasting the sulphide, and then fusing the oxide thus obtained with charcoal.

Properties.—Antimony is a bluish-white, brittle, crystalline solid, isomorphous with arsenic, and resembling zinc in color and lustre. It tarnishes with difficulty, but takes fire at a red heat. It unites readily with chlorine, forming two chlorides, $SbCl_3$ and $SbCl_5$, both of which are decomposed by an excess of water. In physical properties it resembles the metals, with which it forms alloys. In chemical properties, it plays both the positive and negative rôles with facility. It is used as a constituent of type metal, Babbitt's anti-friction metal, Britannia, etc., to give hardness, and to cause them to expand in cooling and completely fill the moulds.

Hydrogen Antimonide, Stibin, Antimoniuretted hydrogen (SbH_3).—A colorless, odorless gas, formed under the same conditions as the corresponding compound of arsenic; *i. e.*, by nascent hydrogen on reducible antimony compounds. It differs from that compound in being much less poisonous, and giving a different reaction with solutions of silver nitrate, as shown in the following reactions:—

$$6AgNO_3 + AsH_3 + 3H_2O = 6HNO_3 + H_3AsO_3 + \underset{\text{Metallic Silver.}}{3Ag_2}.$$

$$3AgNO_3 + SbH_3 = 3HNO_3 + \underset{\text{Silver Antimonide.}}{SbAg_3}$$

By carefully floating a solution of ammonium hydroxide over the silver nitrate solution, after passing the gas through it for some time, a yellow precipitate of arsenite of silver will be formed at the line of separation of the two liquids, while, in the case of antimony, no such precipitate will be formed. This gas is formed in Marsh's apparatus when antimony is present, and it is likely to be confounded with arsenic unless very great pains be taken to avoid it.

The mirrors obtained on the porcelain, or in the delivery tube, require a higher temperature to volatilize them in the case of antimony; they are difficultly soluble in hypochlorite solution, are sooty and less brilliant in appearance, there is no garlic odor, and by oxidation they do not form crystals.

Chlorides, Bromides and Iodides.—Two chlorides and two oxychlorides exist.

Antimony Chloride—A. Trichloride, or **A. Protochloride—Butter of Antimony** ($SbCl_3$) may be obtained by dissolving the trisulphide in hydrochloric acid.

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

At low temperatures it is a crystalline solid, and melts at 73.2° C. (164° F.) to a yellow, oily liquid. A solution of sp. gr. 1.47 is sometimes used as an escharotic. On the addition of considerable water, this chloride is decomposed into the **oxychloride,** ($SbOCl$), formerly called **powder of algaroth.** $SbCl_3$ is poisonous, acting both locally and as a true poison.

Antimony Pentacloride ($SbCl_5$) is a fuming, colorless liquid, of little interest to the medical student. The iodides, bromides, and fluorides are similar to the trichloride in composition and properties. The iodide has been used in medicine.

Sulphides of Antimony.—Two sulphides and several oxysulphides are known. **Antimony Trisulphide — Sulphuret of Antimony — Black Antimony — Antimonii Sulphidum** (U. S. P.), Sb_2S_3, occurs native as a steel-gray, crystalline solid. Artificially, it may be prepared as an orange-colored powder, by precipitating a soluble antimony salt with hydrogen sulphide. When the native ore is roasted in the air it is partially decomposed, and fuses into a vitreous, somewhat transparent mass, known as **glass of antimony,** or **crocus.**

Antimonii Sulphidum Purificatum (U. S. P.) is made by reducing sulphide of antimony to a very fine powder, and then macerating with ammonia water for five days, and finally washing with water and drying. It is a grayish-black powder, having no lustre, and being without odor or taste.

Antimonii Sulphuratum (U. S. P) is a reddish-brown powder prepared by dissolving the native sulphide in a solution of sodium hydroxide, and re-precipitating the hot solution with sulphuric acid. It contains a little antimonous oxide (Sb_2O_3), and is used mostly in pill form. Dose, gr. ij to xx. Plummer's Pill, **Pil. antimonii comp.,** contains this sulphide, with calomel.

By treating a hot solution of the trisulphide with sodium thiosulphate, a fine red precipitate of oxysulphide is obtained, which is used as a pigment, under the name of **antimony vermillion. Kermes' mineral** is another name for sulphurated antimony.

Antimonic Sulphide, or **Antimony Pentasulphide,** (Sb_2S_5) is best obtained by decomposing sulphantimonates with a diluted acid. It is an orange-red or brown powder, readily soluble in alkalies and alkaline sulphides, forming antimonates with the general formula $M_3'SbO_4$, in which M stands for a metallic atom. Sulphantimonates of silver, lead, and iron, occur as minerals.

Oxides and Acids of Antimony.—Three oxides are known.

Antimony trioxide, ... Sb_2O_3, Metantimonous acid $HSbO_2$.
" **pentoxide,** . . . Sb_2O_5.
" **tetroxide,** . . . Sb_2O_4 or SbO SbO_3.

Antimony Trioxide, Antimonii Oxidum U. S. P.—(Sb_2O_3) is obtained by roasting the metal in air, or by treating it with HNO_3 and evaporating the excess of acid. It is a white, amorphous powder capable of being sublimed. It is insoluble in water, alcohol, or nitric acid.

Metantimonous Acid ($HSbO_2$) is obtained as a white precipitate by adding a solution of sodium carbonate to a solution of $SbCl_3$.

$$2SbCl_3 + 3Na_2CO_3 + H_2O = 2SbO_2H + 6NaCl + 3CO_2.$$

By boiling, this acid is changed into the trioxide. It reacts with both acids and alkalies to form salts. Thus, we have $NaSbO_2$, SbO (NO_3), and Sb $(NO_3)_3$. We also have **antimony sulphate** $Sb_2(SO_4)_3$—and **antimonyl sulphate** $(SbO)_2(SO_4)$—the former obtained by dissolving the oxide in strong, and the latter in dilute sulphuric acid. Both are decomposed by excess of water.

Antimonic Acid (H_3SbO_4) is obtained, as a white powder, insoluble in water and nitric acid, by treating antimony with warm concentrated HNO_3.

Pyro-antimonic Acid ($H_4Sb_2O_7$)—is also known, and may be obtained by treating its salts with hydrochloric acid.

By gently heating either of the above acids, antimony pentoxide is obtained as a yellow, amorphous mass, and by a stronger heat, with free access of air, it is converted into tetroxide—Sb_2O_4 —which is usually regarded as an antimonate of antimonyl ($SbO\ SbO_3$). It is a white, non-volatile powder, becoming yellow when heated

Potassium Antimonyl Tartrate.—Tartar Emetic—Antimonii et Potassii Tartras ($K(SbO)C_4H_4O_6.H_2O$) is one of the most commonly employed compounds of antimony.

It is prepared by boiling 3 parts of Sb_2O_3 with 4 parts of cream of tartar ($KHC_4H_4O_6$) in water, for an hour, filtering, evaporating the filtrate, and allowing it to crystallize out. It occurs in small, transparent, rhombic crystals, which effloresce in air, and have a sweetish, afterward disagreeable, metallic taste and acid reaction. Soluble in 17 parts of water at 15° C, (59° F.), and 3 parts boiling water and insoluble in alcohol. Its solutions are incompatible with alcohol, hydrochloric acid, and alkaline carbonates. Free tartaric acid prevents the precipitation by the above reagents. On being heated to redness it chars.

It is used in medicine, and enters into the composition of **Syr. scillæ compositus,** and **Vinum antimonii.** The dose of tartar emetic is gr. j–ij (.065–.125 grm.), as an emetic; as an expectorant, gr. $\frac{1}{16}$ to gr. $\frac{1}{4}$ (.004–.016 grm.); of the wine, 10 to 30 drops.

Physiological Action.—Locally, the soluble compounds of antimony act as powerful irritants Tartar emetic causes a pustular eruption resembling variola, which is accompanied with fever and systemic disturbances. Cases of poisoning from antimony, used as a mordant in dyeing clothing, have been reported. Internally, tartar emetic is employed as an expectorant, sudorific, sedative, nauseant and emetic, according to the dose used. In full doses, it causes vomiting, purging, and griping pains, with great depression. In excessive quantity, it acts as an irritant poison, and has produced death by syncope, preceded by convulsions and delirium. One and a half grains (.092 grm.) have produced death, but recovery has occurred after very large doses, because of the rejection of the poison by vomiting.

The treatment should consist in promoting free vomiting, or removal of the poison with the stomach pump. The proper antidote is tannin, which forms an insoluble compound with antimony; it may be administered in the form of infusion of tea, oak bark, nutgalls, etc. Stimulants are then to be administered.

In suspected cases, examine the urine or viscera by Marsh's test (page 191). Soluble salts of antimony give an orange-colored precipitate with H_2S, in acid solutions, which is soluble in yellow ammonium sulphide, and in strong hydrochloric acid. In Reinsch's test, a bluish stain is obtained, but the sublimate obtained from it is amorphous, not crystalline. (See page 196.)

BISMUTH.

$Bi = 208.9$.

Occurrence and Preparation.—Occurs native and as a sulphide—bismuthite. The element is obtained by roasting the sulphide in air, and reducing the resulting oxide with charcoal, iron being added to take up the remaining sulphur.

Properties.—Bismuth is a white, metallic-looking solid, with a bronze tint. Sp. gr. 9.9. It is brittle, and crystallizes in rhombohedrons; fuses at 267° C. (512.5° F.), volatilizes at a white heat, and if heated in air it burns to Bi_2O_3. HNO_3 and hot H_2SO_4 dissolve it, but HCl does not. Water precipitates basic salts from the solutions of the neutral salts It alloys with the metals, and is sometimes described as a metal.

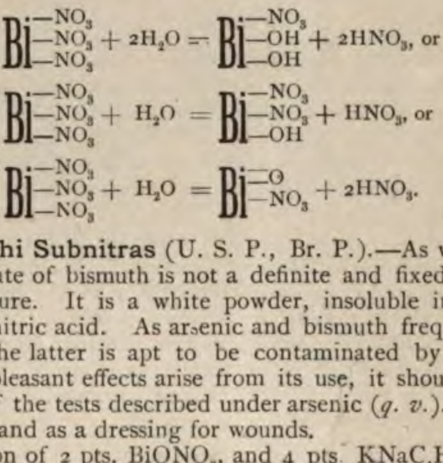
Bismuth Chloride ($BiCl_3$) may be obtained by treating the element with chlorine or aqua regia. It is a soft, white, deliquescent, volatile solid. Water, added to its solutions, precipitates the white **oxychloride.**

$$BiCl_3 + H_2O = BiOCl + 2HCl.$$

This reaction resembles that of $SbCl_3$. BiOCl, as well as the subnitrate, is sold as pearl powder, or pearl white, and is used as a cosmetic. They are blackened by H_2S. The compounds Bi_2Br_4 and BiI_3 are similar to Bi_2Cl_4 and $BiCl_3$. Bismuth does not form a hydride (BiH_3), as does the rest of the group.

Oxygen Compounds.—Bismuth oxide (Bi_2O_3) is a yellow powder, insoluble in water and alkalies; it may be prepared by roasting bismuth, or heating the nitrate or carbonate. When chlorine is passed through a solution of potassium hydroxide, in which Bi_2O_3 is suspended, **bismuthic acid** (BiO_3H) is precipitated as a red powder. On gently heating this, the pentoxide, or **bismuthic oxide** (Bi_2O_5), is formed. Bismuth hydroxide (BiO_3H_3) is precipitated by a solution of NH_4OH from solutions of a bismuth salt. The metahydroxide (BiO_2H) is precipitated when caustic soda or potassa is added to a bismuth solution, or to the nitrate suspended in water. This oxide is the one first precipitated in testing for sugar in Bœttger's test. The oxides Bi_2O_3, Bi_2O_4 and Bi_2O_5 are also known.

Bismuth Nitrate ($Bi(NO_3)_3$) is formed by dissolving bismuth, or the basic nitrate, in nitric acid and evaporating, when it crystallizes in large transparent tables ($Bi(NO_3)_3.5H_2O$). It is soluble in a little water, but is decomposed by a large amount, into a basic nitrate or subnitrate. The reaction varies with the amount of water used.



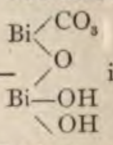
$$Bi\begin{array}{l}-NO_3\\-NO_3\\-NO_3\end{array} + 2H_2O = Bi\begin{array}{l}-NO_3\\-OH\\-OH\end{array} + 2HNO_3\text{, or}$$

$$Bi\begin{array}{l}-NO_3\\-NO_3\\-NO_3\end{array} + H_2O = Bi\begin{array}{l}-NO_3\\-NO_3\\-OH\end{array} + HNO_3\text{, or}$$

$$Bi\begin{array}{l}-NO_3\\-NO_3\\-NO_3\end{array} + H_2O = Bi\begin{array}{l}=O\\-NO_3\end{array} + 2HNO_3.$$

Bismuthi Subnitras (U. S. P., Br. P.).—As will be seen, the subnitrate of bismuth is not a definite and fixed compound, but a mixture. It is a white powder, insoluble in water, but soluble in nitric acid. As arsenic and bismuth frequently occur together, the latter is apt to be contaminated by the former. Should unpleasant effects arise from its use, it should be tested with one of the tests described under arsenic (*q. v.*). It is used internally, and as a dressing for wounds.

A solution of 2 pts. $BiONO_3$, and 4 pts. $KNaC_4H_4O_6$, in 100 c. c. of a strong solution of sodium hydroxide is used as a delicate test for diabetic sugar. It becomes black on boiling, in the presence of glucose, from reduction of the bismuth.

Bismuth Subcarbonate—Bismuthi Subcarbonas (U. S. P.).—**Bismuthi Carbonas** (Br. P.)—  is a light, white, odorless and tasteless powder, insoluble in water, and formed by the action of alkaline carbonates upon solutions of bismuth. Heat changes it into Bi_2O_3, H_2O, and carbon dioxide.

Bismuth Sulphate ($Bi_2(SO_4)_3$) is formed by dissolving bismuth in sulphuric acid. It is of no special interest to physicians.

Bismuth Citrate ($BiC_6H_5O_7$) is a white, amorphous, odorless and tasteless powder, insoluble in water or alcohol, but soluble in ammonium hydroxide. Prepared by boiling the subnitrate in a solution of citric acid, and precipitating the citrate with water. By dissolving the citrate in diluted ammonia water, and cautiously evaporating to a syrup, and spreading on glass, shining, pearly or translucent scales of **Bismuth et Ammonii Citras** are obtained, soluble in water.

Bismuth Subgallate, Dermatol ($Bi(OH)_2\,C_6H_2(OH)_3CO_2$) is a saffron-yellow odorless, tasteless powder, insoluble in water, alcohol, or ether. It is prepared by mixing, with constant stirring, a warm solution of 1 part of gallic acid in 50 parts of water, with a solution of 3 parts of bismuth nitrate in 50 parts of water and 6 parts of glacial acetic acid. It is used as an intestinal antiseptic, and as a substitute for iodoform for external use. The other salts of bismuth used in medicine are the benzoate, salicylate, naphtolate, oleate, phenolate, pyrogallate, tribrom-phenolate and a number of others.

Physiological Action.—The bismuth salts in medicinal doses are tonic, antispasmodic, mildly astringent and anti-fermentative. They are used to allay gastro-intestinal irritation and diarrhœa. When administered in considerable quantities they form black stools, from the presence of the sulphide formed by the H_2S of the intestines. In many cases of excessive diarrhœa, with acid fermentation in the stomach and intestines, this blackening does not occur, and its appearance marks an improvement in the case.

Cases of poisoning by large doses of the salts of bismuth are generally, if not always, due to the presence of arsenic in them.

Tests.—Water precipitates bismuth from its solutions, in the absence of much free mineral acid. Hydrogen sulphide and ammonium sulphide give a black precipitate, insoluble in water, diluted acids and alkaline sulphides. **Potassium, Sodium and Ammonium Hydroxides** give a white precipitate, insoluble in excess of the reagents. Infusion of nutgalls gives an orange precipitate. **Potassium Iodide** gives a brown precipitate, soluble in excess of reagent. A piece of paper dipped in a solution of potassium sulphocyanate and dried, forms a yellow spot when a drop of a solution containing bismuth is dropped on it.

GROUP IV.

Carbon, C = 12.
Silicon, Si = 28.
Germanium, Ge = 72.
Tin (Stannum), Sn = 118.
Lead (Plumbum), Pb = 207.

CARBON.

C = 12.

Occurrence.—Carbon occurs native in the diamond, graphite (black lead), and the various forms of coal. In combination it occurs in all the organic bodies, petroleum, fats, oils, and in native carbonates as marble, dolomite, etc.

Varieties.—Carbon exists in three allotropic states, the diamond, the graphite, and amorphous carbon. The **diamond** occurs in alluvial deposits in Brazil, India, Borneo, South Africa, and in small quantities in other localities. The so-called California diamonds and Brazilian pebbles are crystals of quartz (SiO_2). The diamond is pure crystallized carbon, possessing a brilliant lustre and a high power of refraction, and is the hardest substance known. It crystallizes in rhombohedra of the first system, but cleaves readily into octahedra. It occurs colorless, as well as colored through all shades of yellow, brown and black. The sp. gr. is 3.5. Heated in the oxyhydrogen blowpipe flame, or in oxygen gas, it burns to carbon dioxide, and is slightly softened by the heat of the electric arc.

Graphite, or **Plumbago**, occurs as a native mineral, having a grayish-black color, a lustre almost metallic, and a soapy feel. It leaves a black streak upon a white surface, on account of which it is used to make lead pencils, and is called **black lead.** It sometimes occurs in short, six-sided prisms. It burns in an atmosphere of oxygen, with more difficulty than the diamond, furnishing carbon dioxide, and leaving from 2 to 5 per cent. of ash. Some of the purer varieties can be made directly into pencils, but this is not common. The poorer varieties are ground to a powder, heated with potassium chlorate ($KClO_3$) and sulphuric acid (H_2SO_4), or with strong nitric acid, washed with water, heated to red heat, and then mixed with some adhesive material and pressed into cakes. These cakes are then sawed into suitable strips and mounted.

Graphite conducts heat and electricity well. It is also used in the manufacture of crucibles, as a lubricant for very heavy machinery, and as a stove polish. It may be obtained artificially by fusing amorphous carbon with cast-iron. On cooling the mixture and dissolving the iron with a diluted acid (HCl), graphite is left in the form of minute hexagonal plates. **Amorphous carbon** is found native in the form of many varieties of coal. Artificially, it is prepared by the partial burning, or carbonizing, of organic matter, such as wood, pitch, blood, etc.

Soot, or **Lampblack,** one of the purest forms of amorphous carbon, is prepared by the imperfect combustion of turpentine, pitch, or heavy oils rich in carbon. It is used principally as a pigment. **Animal charcoal or bone black** is obtained by the carbonization of animal matter from slaughter-houses (blood, bones, etc.), and possesses, in a remarkable degree, the power of removing the coloring matter from organic solutions filtered through it. It is used in refining sugar to remove the color from the solution of raw sugar. **Charcoal, Carbo ligni** U. S. P., is carbonized wood, retaining, usually, the form and grain of the wood and the ash contained in the same. In preparing it, the wood, cut into suitable lengths, is piled up on end into a conical heap, a trough made of boards being laid from the circumference on one side to the center, to supply air in burning. The whole heap (except a hole at the centre on the top) is then covered, first with straw or leaves, and finally with dirt about six or eight inches in thickness. The fire is lighted and is allowed to burn slowly, until the flame almost ceases to come from the hole at the top, or until the gaseous products have all burned off. This opening at the top, as well as the draught hole, is now covered over and the fire allowed to smoulder for a time, when the heap is torn down, and the remaining fire extinguished with water.

Charcoal is used as a fuel, in the manufacture of gunpowder, and sometimes in the construction of filters, as it possesses, although in a feebler degree than animal charcoal, the power of destroying noxious odors, and filtering coloring matters from organic solutions. One volume of it absorbs 90 volumes of NH_3, 55 volumes of H_2S, and 9 volumes of oxygen, at 100° C. (212° F.). It is very porous, and burns with little flame. **Coke** is the porous mass left in the retorts from the destructive distillation of mineral coal in the production of illuminating gas. **Gas retort carbon** is a compact, hard mass found adhering to the inside of the retorts in the above process of manufacturing coal gas. It has a metallic lustre, at times, and is a good conductor of electricity.

For this reason and because of its durability it is used for the negative plate in the construction of many forms of the galvanic cell, and for the poles in the arc electric light.

Mineral coals, as anthracite, bituminous, brown and cannel coals lignite, peat or turf, etc., are the results of a slow decay of vegetable matter, under certain conditions. The proper conditions for the formation of coal seem to be, enough water to cover the fallen timber or vegetation, a covering of clay or mud to exclude the air, and the application of pressure to the mass. The liquid and volatile portions are gradually lost, leaving the carbon behind. The final product of this change, assisted by subterranean heat, is **anthracite** coal, which often contains 96 to 98 per cent. of carbon, and almost no volatile products. Petroleum oil is believed to be the expelled liquid portions of the wood, separated from the anthracite coal by heat and pressure. **Bituminous** coal is a softer, less compact, less decayed variety. It often contains the structure of the wood. It burns with a smoky flame, while the anthracite furnishes very little or no flame. **Brown coal, lignite** and **wood coal** are names of less perfect varieties than those before mentioned. **Peat,** or **turf,** is a mixture of mud with partially decayed plants and roots, and is obtained from certain marshy districts. It is used as fuel. **Cannel-coal** is a compact, even-textured coal, without lustre. It takes fire readily, burning with a clear yellow flame. It has been used for candles—hence the name.

Properties.—Carbon is insoluble in all ordinary menstrua, but soluble to a slight extent in molten cast-iron, forming a carbide. It is fused and volatilized only in the electric arc. At ordinary temperatures it is permanent in air. At high temperatures it has a strong affinity for oxygen, and on this account it is used as a reducing agent in smelting the ores, from which it removes the oxygen. Indirectly, it enters into combination with a great many of the elements. Organic bodies are formed of carbon in combination with hydrogen, nitrogen, and oxygen. Most combustible bodies contain carbon.

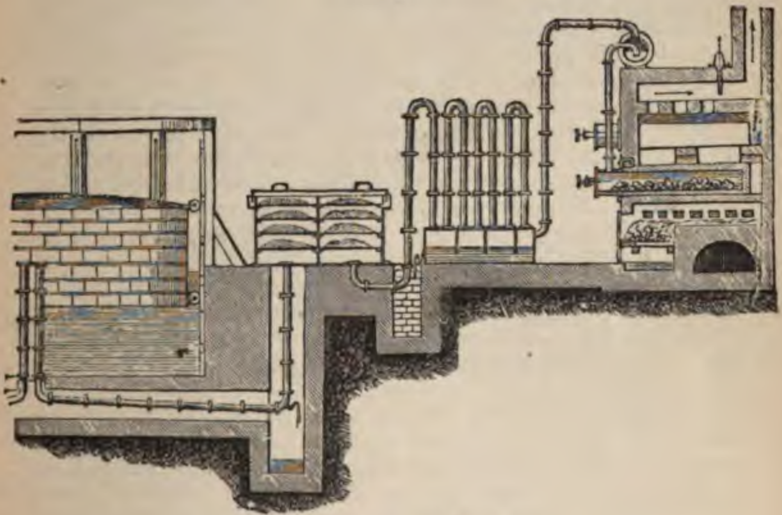
Official Preparations.—Animal Charcoal, Carbo Animalis, U. S. P., is charcoal prepared from bones by partially burning them, and distilling off the volatile products and charring the remaining organic matter. It occurs in granular fragments, or in powder of a dull black color, which, when ignited, leaves about 85 per cent. of ash. This ash should be almost entirely soluble in hot HCl.

When animal charcoal is boiled for a few minutes with a solution of potassium hydroxide, the filtered solution should be colorless, or nearly so.

Carbo Animalis Purificatus, U. S. P.—This is prepared by heating the above with diluted HCl to dissolve out the calcium phosphate. The quantity of ash after ignition should not be more than 4 per cent.

Carbo Ligni, U. S. P., is prepared from soft wood, and very finely powdered. It should be kept in well-closed vessels.

FIG. 58.



THE MANUFACTURE OF COAL GAS.

Coal Gas.—Illuminating gas, as it is often called, is made on a large scale by the dry or destructive distillation of bituminous coal In principle, the manufacture is simple; but in practice, it requires considerable skill to prepare a good illuminating gas. During the distillation, which is conducted in horizontal semi-cylindrical fire-clay or cast-iron retorts set in brickwork, a variety of products are produced besides the gas; such as tar, heavy oils, lighter oils, steam, ammonia from the nitrogen of the coal, etc. There is left in the retort a porous, friable mass called **coke.** After the retorts have been used for some weeks, there is to be found lining their inner surfaces a very compact layer of carbon, usually known as **gas retort carbon.**

The coal is distilled at a bright red heat, and the volatilized products are conducted into a large horizontal iron pipe, half filled with water, into which the pipes from the retorts dip. (See Fig. 58.) This is called the **hydraulic main.** A large part of the **coal tar** and heavy oils condense in this main. The volatile products are then made to traverse a series of upright tubes, in the form of an inverted U, called condensers. The lower end of one limb of each condenser dips under water, so as to cool the gas and to wash out the ammonia. After traversing a number of these condensers, where the remainder of the tar, steam, and ammonia are condensed, the gas passes to the purifiers. These are composed of a series of large boxes, in which are several perforated shelves, or trays, holding fresh slaked lime, or a mixture of sawdust and iron oxide. The gas is passed slowly through these purifiers, so as to expose it to the action of the lime or iron oxide, to remove H_2S, CO_2, and other volatile acids, if present. In some plants there is an additional process of washing the gas by passing it through weak sulphuric acid to remove the small quantity of ammonia still remaining. The tar and ammonia liquor are sold as by-products. The latter furnishes a very considerable portion of the ammonium compounds of the market. After passing through the purifiers, the gas is conducted in underground pipes to the gasometer, to be stored until needed.

The **gasometer** is a very large, tub-shaped vessel, made of boiler-iron, floated bottom upward upon water. It is balanced by weights attached to chains passing over pulleys at the top of iron pillars, which are erected around the gasometer for that purpose. As the gas is forced into the gasometer, the latter rises out of the water, and sinks again as the gas is used.

Various other processes for the manufacture of gas have been used with varying success; such as the distillation of the heavy petroleum oils, either alone, with coal, or with the admixture of the vapors with air or steam.

Gasoline, or **air gas,** is air saturated with the vapors of the very volatile oils from petroleum.

Water Gas is very largely used in all large cities, owing to the cheapness of its manufacture It is made by the action of steam upon coal heated to a red or white heat. The gas thus produced is, in some works, mixed with vapor from naphtha, and then again strongly heated in retorts, and finally purified as in ordinary coal gas.

Composition.—The composition of coal gas varies somewhat with the composition of the coal used, and the temperature of the retorts during the distillation.

The following figures represent the composition of coal gas and water gas supplied to Brooklyn in 1883:—

	Coal Gas.	Water Gas.
Carbon dioxide,	0.0	0.3
Carbon monoxide,	7.9	28.25
Hydrogen,	50.2	30.3
Illuminants (C_2H_4, C_2H_2, etc.),	4.3	12.85
Marsh gas (CH_4),	29.8	21.45
Nitrogen,	7.8	6.85
	100.00	100.00

Carbon forms with chlorine the following compounds: carbon tetrachloride, CCl_4, carbon chloride, C_2Cl_2, carbon dichloride, C_2Cl_4, carbon trichloride, C_2Cl_6, and the oxychloride, $COCl_2$.

It combines directly with some of the metals to form carbides. The carbide of iron is a familiar example. The carbide of calcium has recently been found a valuable commercial product.

Carbon and Oxygen.—There are four oxides of carbon known, having the formulæ C_8O_3, C_4O_3, CO, and CO_2. The first of these compounds is a light brown powder, formed by heating the suboxide (C_4O_3).

Carbon Suboxide is an amorphous extractive matter formed by the action of an electric current upon carbon monoxide.

Carbon Monoxide (CO) is a colorless, tasteless, almost odorless, combustible, and very poisonous gas.

It is always produced when carbon or bodies containing it are burned with an insufficient supply of oxygen or air, or by conducting carbon dioxide over or through red-hot coals. $CO_2 + C = 2CO$. It may be prepared by warming oxalic acid with sulphuric acid.

$$H_2C_2O_4 + H_2SO_4 = H_4SO_5 \text{ (or } H_2O.\ H_2SO_4) + CO_2 + CO.$$

The mixed CO_2 and CO are passed through a solution of sodium hydroxide to absorb the CO_2, and the CO remains. One part of potassium ferrocyanide, warmed with nine parts of H_2SO_4, may be used to give the gas in nearly a pure state. Its density is 14. It is almost insoluble in water, but soluble in a solution of cuprous chloride in ammonium hydroxide. It burns in the air with a bluish-lavender flame, producing the higher oxide—CO_2. Owing to this property, it plays an important part in the reduction of ores in the blast furnace. It does not support combustion or respiration. It diffuses readily through red-hot cast-iron, and frequently escapes from stoves and hot-air furnaces.

Physiological Effects.—It has the power of combining with the hæmoglobin of the blood, and of expelling the oxygen. It thus acts as a narcotic poison, causing dizziness, headache, nausea, inco-ordination of movements, convulsions, and death. If the carbon monoxide be in sufficient quantity to saturate all the hæmoglobin, recovery is seldom, if ever, realized. The blood has a light-red color, and does not coagulate after death, or decompose as readily as normal blood. When diluted and examined with the spectroscope, it gives two absorption bands similar to those in No. 10 Frontispiece, but they are removed somewhat toward the violet end of the spectrum. If the hæmoglobin is only partially saturated, recovery may take place, but very slowly—debility, anorexia, etc., remaining for days. Air containing 0.5 per cent. kills birds in three minutes; 2 per cent. renders a guinea pig insensible in two minutes. Artificial respiration is of little use Transfusion of blood or intra-venous injection of sterilized salt solution, 0.7 per cent., is the most promising treatment. The sources of danger are open fires, defective draught in chimneys, escape of coal gas, and especially "water gas" from defective fittings, or from leaks under the ground. When the ground is frozen and the gas escapes into the soil near a cellar, the gas diffuses through the ground into the cellar, and, as it is thus deprived of its odor, persons may be poisoned and not know where it comes from. Coal-gas poisoning is essentially a poisoning by the carbon monoxide which it contains. Suffocation by coal-gas is not very different from suffocation by other gases, and should be distinguished from poisoning.

Carbon Dioxide—Carbonic Anhydride (CO_2), sometimes called carbonic acid gas, is found free in the air in the proportion of about 4 parts per 10,000, and in ordinary well-ventilated rooms from 5 to 6 parts per 10,000. It is found in volcanic gases, and in solution in many mineral springs. It sometimes accumulates in dangerous quantities in mines, wells, and cellars, and is then known as "choke damp." It may be detected in such places by lowering a candle. It is produced when carbon or its compounds are burned with a free supply of air, by alcoholic and other fermentations, by the respiration of animals, and by slow oxidation of organic matter in the natural process of decay. In the laboratory, it is obtained by the action of an acid upon a carbonate.

$$CaCO_3 + 2HCl = CO_2 + CaCl_2 + H_2O.$$

Carbon dioxide, at ordinary temperatures and pressures, is a colorless, transparent, odorless, tasteless (by some thought to be sweetish) gas. Sp. gr. = 1.524. Density = 22. Under a pressure of 36 atmospheres at 0° C (32° F.), it is condensed to a colorless, mobile liquid, of sp. gr. 0.94. Above 32.5° C., it cannot be liquefied at any pressure. This is known as the **critical point in temperature.** When the liquid is exposed to the air it rapidly evaporates, producing a temperature so low as to freeze a portion of it to a snow-like solid, the temperature being sometimes as low as —130° C. (−202° F.). The gas extinguishes the combustion of burning bodies, and animals die very quickly in it. Death has resulted from persons entering mines, wells, and fermenting vats where the gas has accumulated. It is unsafe for a man to venture into a well or other place where a candle will not burn. CO_2 is soluble in its own volume of water, at tne ordinary temperature and pressure, forming a solution of carbonic acid, H_2CO_3. Common **soda water** is a solution of the gas in water under pressure: it contains no sodium salt, as its name would imply.

Physiological Effects.—These vary with the degree of concentration of the gas and its dilution with other gases. If the gas be pure, it causes death instantly, by apnœa from spasm of the glottis. When somewhat diluted there is, at first, great loss of muscular power: the person becomes livid, sinks down, and dies without a struggle. When still more diluted there is, at first, irritation of the throat, then giddiness, ringing in the ears, loss of muscular power, with rapid pulse and respiration, and occasionally vomiting and convulsions, which finally end in coma and death.

The amount of the gas that can be tolerated in the air depends not only upon the quantity of it actually present, but also upon the source of it. Thus, when the source of the gas is animal respiration or combustion, the oxygen is withdrawn from the air at the same time, and a much smaller quantity will prove fatal than where the gas is simply added to the normal atmosphere.

If the CO_2 is simply added to the air, 10 per cent. may be regarded as poisonous, and even 8 per cent. will prove injurious. If, on the other hand, the oxygen be increased, an air containing even 20 per cent. may be breathed by animals for a short time without fatal results. A taper will burn in an air containing 8 per cent. of CO_2 provided the oxygen be present in normal quantity, and will burn feebly in such an air containing 10 per cent. Where the CO_2 is produced by respiration, the injurious effects are soon perceived; and are due to several causes, viz.: the deficiency of oxygen, the presence of too great a quantity of CO_2 and moisture, the rise in temperature, and the action of the organic matter exhaled from the lungs and skin.

The expired air contains from 4 to 5 per cent, or about .78 cubic feet of CO_2 per hour, and there is absorbed .94 cubic feet of oxygen. A stearin candle gives off .5 cu. ft. of CO_2, and uses up 1 cu ft. of oxygen. A gas light burning 5 feet of gas per hour (12 candle power) gives off very nearly 6 cu. ft. of CO_2, or 3.7 times as much as one man; as much heat as two men; removes more oxygen than 5 men; and gives off nearly as much water vapor as 5 men. More than 6 parts of CO_2 per 10,000 of air, renders it oppressive, and should not be allowed. Assuming the amount of CO_2 given off in an hour by an adult to be 7 cu. ft., and normal air to contain 4 parts, it would require about 3500 cu. ft. of air per hour for each adult occupant of a room, in order that it should not receive more than two parts per 10,000 of CO_2, or two cubic feet per 10,000. Dr. Parkes fixes the amount necessary at 2000 cu. ft. per hour. It is impossible to change the air of a room oftener than 3 or 4 times per hour without causing uncomfortable draughts; and it would, therefore, require 700 to 1000 cu. ft. of room space in order to keep the air of the room in a proper condition. If lights are used, which also pollute the air, a corresponding calculation must be made for them. A common oil lamp, or two sperm candles (not an argand lamp), will contaminate the air about the same as an adult man. The English Poor-Law Board's requirements for dormitories, to prevent over-crowding, are—

Cu. ft.	
1200	Lying-in cases and offensive sick.
850	Sick.
700	Infirm. Same room night and day.
500	Infirm. Separate room in day.
300	Healthy.

These figures are, of course, too small for general use. Parkes quotes Morin as giving the following amount of fresh air necessary to be furnished to each adult per hour in the following circumstances:—

	Day.	Night.
In Barracks, . . .	1059 cu. ft. per hour.	2118 cu. ft. per hour.
" Workshops, . .	2118 " "	
" Schools, . . .	1059 " "	
" Hospitals, . . .	2825 " "	

In sleeping apartments, the amount of space allowed to each individual should not be less than 1000 cubic feet, *i. e*, a room 10 × 10 × 10 ft. But, as the proportion of carbon dioxide would accumlate slowly, and as a much larger amount of the gas may be borne without serious discomfort, even one-half this capacity may be tolerated with little inconvenience beyond a feeling of fatigue or sleepiness in the morning. Dr. Tidy regards 400 cubic feet as the very smallest amount of space that should be allowed to each person in a sleeping room, to avoid serious overcrowding. Analysis shows that the foulest air in an occupied room is at the ceiling. The heat of the body or of a lamp causes an expansion of the air about them, and an upward current of heated CO_2, water vapor, etc. These gases reach the ceiling before they cool sufficiently to stop this upward current, and before there is time for perfect diffusion. The upper galleries in theatres are supplied with impure air from the main floor and lower galleries and from the gas lights. Fresh air should always be admitted to a room near the floor, and the outlet for impure air should be at or near the ceiling. It must be remembered that the law of diffusion of gases does not allow the CO_2 to accumulate in one part of the room and remain there for any considerable time, but mixes it evenly through the air.

Nor is this diffusion confined within a room. It takes place through porous walls between the indoor and outdoor air, especially in winter, **when there is much difference in the temperature of the two.** Indeed, a very fair amount of ventilation may be affected in this way, where the walls are of brick or stone, and not papered or painted inside

Carbon dioxide exists in the blood partly in solution in the serum, partly combined as sodium bicarbonate, partly as sodium phospho-carbonate, and partly combined with the corpuscles of the blood. Putrefaction after CO_2 poisoning is slow, while animal heat and rigidity are very persistent.

Tests for Carbon Dioxide.—If the quantity exceeds 12 per cent., a taper is extinguished. Lime water and baryta water absorb CO_2 from the air, and are rendered cloudy by it, from the precipitation of the carbonates of calcium or barium.

Advantage is taken of this fact to estimate the quantity of CO_2 in air. A simple way of testing whether the air of a room contains too much CO_2 is to select a quart bottle, fill it with the air of the room by first filling the bottle with water and then pouring it out slowly, and add to the bottle one cubic centimeter (♏xvss) of clear and well-saturated lime water, faintly colored with phenolphthalein. Add a little pure water, cork, shake, and let stand for a few hours. Pure outdoor air contains just sufficient CO_2 to decolorize the lime-water. Indoor air should not decolorize more than 1.3 c.c. of lime-water.

Carbonic Acid and Carbonates.—CO_2 is soluble in water, with which it combines to form carbonic acid (H_2CO_3).

$$H_2O + CO_2 = H_2CO_3.$$

Carbonic acid is a feeble, dibasic acid, forming a double series of salts, the **carbonates** and **acid-** or **bi-carbonates.** As mentioned above, "soda water" is a solution of carbonic acid in water, kept under pressure. When the pressure is removed, a large portion of the acid undergoes decomposition, into the anhydride (CO_2), and water. The same decomposition, with effervescence, takes place when we prepare the acid by treating a carbonate with a stronger acid. The carbonates of gold, arsenic, antimony, and aluminum are unknown. The carbonates of the alkaline metals are soluble in water, and are not decomposed by heat; while the carbonates of all the other metals are insoluble, and are decomposed by heat, giving the oxides of the metals. The bicarbonates are formed by passing carbon dioxide through solutions of the alkaline carbonates. They are converted into the carbonates again by heat. The carbonates of ammonium are volatilized by heat. Water charged with carbonic acid dissolves the carbonates of some of the metals, as calcium, magnesium, iron, copper, lead, etc., which gives rise, in the case of the first two, to hard water. This hardness is deposited again on boiling the solution, or even on free exposure to the air, thus forming an important element in certain geological formations.

Carbon and Sulphur.—Carbon Disulphide (CS_2)—**Carbonei Disulphidum** (U. S. P.)—is formed, like the dioxide, by the direct union of the elements. When the vapor of sulphur is passed over charcoal heated to redness, the elements combine, producing the vapor of carbon disulphide, which condenses into a very volatile, colorless, mobile liquid, possessing a peculiar, disagreeable odor. It refracts light strongly, and for this reason is used to fill hollow glass prisms for the spectroscope. It is combustible, burning with a blue flame, and has been suggested as a means of furnishing sulphurous oxide for fumigation, by burning a mixture of CS_2 and alcohol in a lamp. Sp. gr. 1.268 to 1.269 at 15° C. (59° F.).

The vapor mixed with air, forms an explosive mixture, and mixed with nitrous oxide, it burns with a very brilliant flame. It is insoluble in water, but is miscible with alcohol and ether. It is a ready solvent for sulphur, phosphorus, caoutchouc (India rubber), fats, oils, and iodine, with the last of which it forms a violet-red solution. CS_2 dissolves in a solution of the alkaline sulphides, forming **sulpho-carbonates.** $CS_2 + K_2S = K_2CS_3$. CS_2 may be regarded as the anhydride of sulpho-carbonic acid, H_2CS_3, obtained by adding hydrochloric acid to a sulpho-carbonate.

Pharmacopœial requirements.—Carbon disulphide should not affect the color of blue litmus paper moistened with water (absence of sulphur dioxide). It should leave no residue when evaported spontaneously (absence of sulphur). Test solution of lead acetate should not be blackened when agitated with it (absence of hydrogen sulphide). **Carbon Monosulphide** (CS)—a brown-red powder, and a sulphide having the formula C_5S_2, and an oxy-sulphide, COS, are also known.

Carbon and Nitrogen. Preparation.—Although carbon and nitrogen cannot be made to unite directly, yet carbon compounds containing nitrogen, when heated with potassium hydroxide, yield potassium cyanide (KCN); and, in the presence of iron, form potassium ferrocyanide, or **yellow prussiate of potash.** From these two compounds all the long list of compounds containing the radial CN are prepared.

Cyanogen is most easily prepared by heating mercuric or argentic cyanide, or by mixing two parts of well-dried potassium ferrocyanide and three parts of mercuric chloride.

Properties.—Cyanogen is a colorless gas, possessing a pungent odor. It is soluble in one-fourth its volume of water, and one-twentieth its volume of alcohol. It is easily condensed to a liquid at —20.7° C. (—5° F.), or at ordinary temperatures by a pressure of 4 atmospheres. At —34° C. (—29.2° F.) it freezes to a snow-like solid. It burns in the air with a purple-red flame. The free cyanogen molecule is composed of two cyanogen radicals, CN—CN. The radical CN—(Symbol Cy) is a monad, negative, or acid radical, resembling the chlorine group in its chemical behavior, and forming a series of cyanides resembling the chlorides, thus :—

Potassium chloride,	KCl.	Potassium cyanide,	KCy.
Silver chloride,	AgCl.	Silver cyanide,	AgCy.
Mercuric chloride,	$HgCl_2$.	Mercuric cyanide,	$HgCy_2$.

Hydrocyanic Acid—Prussic Acid (HCy) is most readily obtained by decomposing the metallic cyanides with sulphuric or hydrochloric acid.

$$KCy + H_2SO_4 = HCy + KHSO_4.$$
$$AgCy + HCl = AgCl + HCy.$$
$$2K_4FeCy_6 + 6H_2SO_4 = FeK_2FeCy_6 + 6KHSO_4 + 6HCy.$$

The acid boils at 26.5° C. (79.7° F.), and is soluble in water, from which it gradually escapes. It is a colorless liquid, of a characteristic odor and taste, resembling those of bitter almonds, the oil of which contains from 5 to 14 per cent. of this acid. It is also a constituent of laurel water.

Acidum Hydrocyanicum Dilutum (U. S. P. and Br. P.) contains two per cent. of HCy, while the French Pharmacopœia directs the acid to contain 10 per cent.

Preparation.—The U. S. P. directs that potassium ferrocyanide be treated in a retort with sulphuric acid and the resulting HCy distilled into a receiver containing some water. The product is then assayed, and diluted with distilled water to bring it to the strength of two per cent. A formula is also given for preparing the acid extemporaneously. Silver cyanide and hydrochloric acid are shaken in a glass-stoppered bottle, and when the precipitate has subsided, the clear liquid is poured off.

Cyanides.—Prussic acid forms a series of compounds known as cyanides, which resemble the haloid compounds. Like the acid, they are all more or less poisonous. The cyanides of potassium, mercury, and silver are best known. The first is soluble in water, the other two are insoluble. The potassium salt is used largely in photography and in electro-metallurgy.

Toxicology. Hydrocyanic acid and the cyanides are very poisonous. One drop of the pure acid is enough to cause instant death. Accidents are liable to occur from the use of the cyanides, or from the acid or vegetable substances containing **amygdalin,** a body which easily undergoes decomposition into prussic acid and other products. Bitter almonds, cherry-laurel, the pits of the common cherry, plum, peach, and sloe, may be mentioned as the most common of these. In England, poisoning by cyanides ranks second in order of frequency in all cases of poisoning. One grain of HCy and 2.4 grains of potassium cyanide are sufficient to cause death in man. The symptoms of poisoning by HCy and KCy are very nearly the same—first a salivation, then constriction of the throat, giddiness, and insensibility. The person then falls, usually in a convulsion, respiration and pulse become irregular, and finally cease. The symptoms commence from ten seconds to one minute after swallowing the poison, depending somewhat upon the dose and form of administration. In some cases death is almost instantaneous; in others, it is prolonged to 15 minutes, or longer. Hydrocyanic acid enters the blood, forming a compound with the hæmoglobin, passes to the medulla, and paralyzes the respiratory centres. The **post-**

mortem appearances are mainly those of suffocation, and everywhere there is the odor of the acid, unless concealed by putrefactive odors. When potassium cyanide has been used, there is usually inflammation of the stomach, due to its caustic action.

Chronic Poisoning by Cyanides may occur in photographers, gilders, and electro-platers. The symptoms are headache, giddiness, noises in the ears, pains in the region of the heart, difficult respiration, loss of appetite, nausea, obstinate constipation, full pulse, pallor, and offensive breath.

Treatment.—When there is time, use cold douches, ammonia inhalations, chloride of lime alone or moistened with vinegar and held to the nose, friction, electricity, artificial respiration. The best antidote is a mixture of ferrous and ferric sulphates, with sodium or potassium hydroxide or carbonate. Usually, however, there is not sufficient time to apply these remedies, except in cases of poisoning by the vegetable substances above mentioned as containing it, and in chronic poisoning.

Tests.—1st. Silver nitrate precipitates the acid as silver cyanide—a white, curdy precipitate, insoluble in cold or weak nitric acid. A glass rod moistened with $AgNO_3$ and held in the vapor is rendered milky. 2d. Add a solution of **liquor potassæ,** or potassium hydroxide, then a solution of ferrous sulphate mixed with ferric sulphate, then a small quantity of sulphuric acid, when a blue deposit of Prussian blue will appear. 3d. To a small portion of the suspected liquid, in a wide test tube or crucible, add diluted sulphuric or hydrochloric acid. Invert over this a watch glass, convex side down, with one or two drops of yellow ammonium sulphide upon the under side of it. Warm the crucible gently, and after a few minutes remove the watch glass, warm, and evaporate the ammonium sulphide by blowing upon it. Now touch the stain with a drop of ferric chloride, when a blood-red stain will make its appearance, due to the formation of sulphocyanate of ammonium on the glass, which, with the iron, strikes a red color. This is easy to perform, is applicable to organic mixtures, and is quite delicate.

Assay.—Mix in a flask of about 100 c.c. capacity, 0.270 gm. of the HCy to be tested, with a little water, and enough magnesia to make the mixture opaque. Add to this two or three drops of test solution of potassium chromate, and then $\frac{N}{10}$ silver nitrate solution from a burette, until a permanent red tint is produced. Each c.c. of the silver nitrate solution used represents 1 per cent. (or 0.0027 gm.) of pure HCy.

Cyanic Acid (H–O–Cy).—Metallic cyanides readily take up oxygen when fused with potassium nitrate or even the oxides of some of the metals, and form cyanates. The acid, HOCy, may be prepared by decomposing its salts with diluted acids. It is unstable, and breaks up into carbon dioxide and ammonia.

$$HOCN + H_2O = NH_3 + CO_2.$$

Of the cyanates, the ammonium cyanate is the most interesting, as its solution in water, on being heated, forms urea, a body isomeric with it, and a well-known excretory substance found in urine.

$$NH_4CNO = CO(NH_2)_2.$$

This is interesting as being the first animal substance prepared by synthesis.

Sulphocyanates.—The potassium salt is prepared by fusing potassium ferrocyanide and sulphur together, and exhausting the fused mass with alcohol. On evaporating the alcohol, a white, crystalline salt is obtained, soluble in water, and having the formula KSCy.

Ammonium Sulphocyanate (NH_4SCy) is prepared by heating hydrocyanic acid with yellow ammonium sulphide.

The principal interest attached to these salts is their use as tests for ferric iron salts, with which they give a blood-red solution. The sodium salt is found in traces in human saliva.

Mercuric sulphocyanate, formed by precipitating mercuric nitrate with potassium sulphocyanate, is decomposed by heat, the mass swelling up and leaving a voluminous residue. It is used in making the toy, **Pharaoh's Serpents.**

Compound Cyanides.—Cyanogen shows a remarkable tendency to form complex compounds. Among these more complex compounds are two series of bodies in which cyanogen and iron form the radical. Of these, the **ferrocyanides** and **ferricyanides** of potassium and iron will be mentioned here.

Potassium Ferrocyanide—$K_4Fe(CN)_6$—**Yellow Prussiate of Potash** is an important commercial product, manufactured on a large scale by fusing in a closed crucible nitrogenous animal matter (horns, hoofs, leather scraps, etc.), with potassium carbonate and iron filings, treating the fused mass with water, and crystallizing. The salt is thus obtained in large, yellow, tabular crystals. It is used in dyeing, in preparing certain pigments, and as a source of all the other cyanogen compounds. By simple fusion, potassium cyanide (KCy) is prepared.

$$K_4FeCy_6 = 4KCy + FeC_2 + N_2.$$

From a solution of the salt, various other ferrocyanides are prepared by precipitation. Of these, **Prussian Blue** (ferric ferrocyanide), prepared by adding to a solution of potassium ferrocyanide a solution of some ferric salt, is used as a pigment and as a medicine. With a ferrous salt the precipitate is white, but quickly becomes blue by oxidation. This test serves to distinguish ferrous from ferric salts. With cupric salts we obtain a reddish-brown precipitate, Cu_2FeCy_6.

Ferricyanides.—By passing chlorine through a solution of K_4FeCy_6, a compound is formed in which the iron of the radical is tetrad, and the radical itself becomes hexad. $K_6(Fe_2Cy_{12})^{vi}$. On evaporating, we obtain dark red crystals of **potassium ferricyanide,** or **red Prussiate of potash.** With ferrous salts a solution of this salt gives a deep blue precipitate of ferrous ferricyanide—$Fe_3Fe_2Cy_{12}$—Turnbull's Blue. Ferric salts give no precipitate or coloration, and thus we distinguish ferric from ferrous salts.

Ferric Ferrous cyanide = Prussian Blue.
Ferrous Ferric cyanide = Turnbull's Blue.

The further consideration of the carbon compounds will be found in Part IV.

SILICIUM—SILICON.

Si = 28.

Occurrence.—It occurs in native rocks, either as silicic oxide (SiO_2), **quartz, amethyst, carnelian,** etc., or combined with various metallic oxides as silicates. **Clay** is principally a silicate of aluminum colored with iron and vegetable matter. This, next to oxygen, is the most abundant of the elements. Neither the element nor its compounds are of much interest to medical students.

The element never occurs native, and may be prepared in three allotropic states:—**amorphous silicon, graphitic silicon,** and **crystallized silicon,** somewhat resembling the three states of carbon.

Compounds.—**Silicic Hydride** (SiH_4) is obtained as a colorless, spontaneously inflammable gas, by the electrolysis of a solution of common salt, using for the positive electrode an aluminum containing silicon. Silicic chloride ($SiCl_4$) is a colorless, volatile liquid possessing an irritating odor. The bromide, $SiBr_4$, and fluoride, SiF_4, are also known. This latter is decomposed by water, forming **hydro-fluo-silicic acid,** H_2F_6Si.

Silicic Oxide, or Anhydride (SiO_2) is the only known oxide of this element, and exists in a pure state in quartz crystal. It may be prepared artificially by adding hydrochloric acid to a concentrated solution of soluble or water-glass, filtering, washing, and heating the residue to expel the water. Artificially prepared, it is a fine, white, tasteless powder, fusible with great difficulty, and not sensibly soluble in water or acids, with the exception of hydrofluoric acid. Its sp. gr. is 2.66. When fused with potassium or sodium carbonates or hydroxides, it forms a silicate of these metals, or glass. When these alkalies are in excess, the glass is soluble in water, the degree of solubility increasing with the proportion of alkaline salt used. This compound is known as **soluble** or **water glass.**

Silicic Acid and Silicates.—The normal cilicic acid has the formula H_4SiO_4, and is only known in solution in water. It may be prepared by adding hydrochloric acid to a very dilute solution of an alkaline silicate, but it is unstable. The acid is very prone to liberate a portion of its water and form acids of the condensed types; *i. e.*, two or more molecules unite and liberate one or more molecules of water. The native silicates are very complex in structure, and are usually formed on this condensed plan.

Glass.—Common glass is a mixture of several silicates, in which there is an excess of silica; the principal ones used being sodium, calcium, and lead silicates. By the addition of small quantities of metallic oxides, various colors are imparted to the glass; thus, cobalt gives a blue, manganese an amethyst, cuprous oxide a ruby, cupric oxide a bluish-green, chromium a greenish-yellow, ferric oxide a brownish-yellow or black, and ferrous oxide the ordinary green bottle glass.

The element **Germanium** is not of sufficient interest to merit an extended description here.

TIN (Stannum).

Sn = 118. Sp. gr. = 7.3.

Occurrence.—Tin was known before the Christian era. It is said to have been found native. The chief ore is **cassiterite,** or **tin stone,** SnO_2. The metal is not abundant and the mines are but few. Those of Cornwall and Banca are best known. Commercial tin is seldom pure, but is liable to contain lead, copper, iron, zinc, antimony, or arsenic.

Properties and Uses.—Tin is a bluish-white, soft metal, malleable, ductile, and fusing at 220° C. (428° F.). At 100° C. (212° F.) it may be drawn into wire, but at 200° C. it is so brittle that it may be pulverized. It oxidizes readily when in the melted state, and at higher temperatures it takes fire and burns to SnO_2. At ordinary temperatures it is fairly permanent in the air. It dissolves in hot hydrochloric acid and in diluted nitric acid, and in hot concentrated solutions of sodium and potassium hydroxides. As tin does not tarnish in the air, or is not easily attacked by the organic acids, it is much used to prepare culinary vessels. Owing to its cost and brittleness it is usually employed to coat over sheet iron and copper. Ordinary **sheet tin** is sheet iron covered with tin by immersing the previously cleansed iron in a bath of melted tin. To prevent the oxidation and waste of the tin while in the melted state, it is covered with a layer of melted tallow. The article to be tinned is dipped through the tallow into the melted tin, thence into another bath of tallow to allow the excess of tin to run off.

An alloy of tin and lead is largely used for tinning iron and copper, to cheapen the cost. This alloy is corroded by ordinary water, and should never be used for culinary vessels or for canning vegetables or fruits, on account of the lead. Brass and copper articles may be given a thin layer by immersing them in a boiling solution of tin chloride in contact with pieces of metallic tin. Mirrors are coated with an amalgam of tin in such a way as to exclude all air. The ordinary tin foil, used as wrapping material, is made by rolling a sheet of lead between two sheets of tin.

Compounds.—Tin forms two classes of compounds corresponding to the dyad and tetrad conditions respectively. Of these the most important are the following :—

	STANNOUS COMPOUNDS.	STANNIC COMPOUNDS.
Chlorides, ...	$SnCl_2$	$SnCl_4$.
Oxides, ...	SnO.	SnO_2.
Hydroxide, ...	$Sn_2O(OH)_2$.	. . .
Acids, ...		H_2SnO_3.
Metastannic Acid, ...		$H_{10}Sn_5O_{15}$.
Chlorostannic Acid, ...		H_2SnCl_6.
Nitrate, ...	$Sn(NO_3)_2$.	$Sn(NO_3)_4$
Sulphate, ...	$SnSO_4$.	$Sn(SO_4)_2$.
Sulphide, ...	SnS.	SnS_2.

Of these compounds the most important is stannous chloride, $SnCl_2$. It is prepared by treating tin with dry HCl, or mercuric chloride. When tin is dissolved in HCl and the solution is evaporated down and cooled, it deposits crystals of $SnCl_2.2H_2O$. These crystals dissolve in about one-third their volume of water, but are decomposed by a large quantity of water into a basic salt. When the solution of this salt is exposed to air, it absorbs oxygen and deposits an oxychloride. Stannous chloride is a strong reducing agent, and is used as such in the laboratory. It is used as a mordant in dyeing. Hydrated stannous sulphide is produced as a brown powder when H_2S is conducted through a solution containing a stannous salt. It is insoluble in diluted acids, but soluble in alkaline sulphides.

Stannic oxide (SnO_2) occurs native in the mineral cassiterite. When prepared artificially, by roasting tin or the hydroxide, it appears as a white powder. It is used in the manufacture of opaque white glass. Stannic oxide is used as a polishing powder under the name of "**putty powder**."

The tin salts have found little use in medicine.

Toxicology.—The salts of tin have feeble toxic properties. The chlorides are poisonous, belonging to the irritant poisons. As the chlorides are used in dye works, they have been taken by mistake, and have caused death or serious symptoms. The symptoms do not appear to be constant or uniform, but there is usually vomiting, pain, depression of the heart's action, diarrhœa, and delirium.

The treatment is to encourage vomiting and give milk freely. Ammonium carbonate may be given, which precipitates the tin in a comparatively insoluble and inert condition. The chlorides are decomposed by nearly all the animal fluids, and also by vegetable infusions.

The effects of small doses of tin continued for a long time have not been clearly defined.

LEAD (Plumbum).

Pb. = 207.

Occurrence.—The most abundant ore found native is **Galena,** or **Galenite** (PbS). Other ores are **Cerussite** ($PbCO_3$), **Crocoisite** ($PbCrO_4$), **Wulfenite** ($PbMoO_4$), and **Pyromorphite** ($Pb_3(PO_4)_2$).

Preparation.—For this purpose **galenite** is almost exclusively employed. The ore is first roasted in the air, by which a portion of the lead sulphide is converted into oxide, and another part into sulphate.

$$2PbS + 3O_2 = 2PbO + 2SO_2$$
$$\text{and } 2PbS + 4O_2 = 2PbSO_4.$$

These two products are then strongly heated in a reverberatory furnace, when they react as follows:—

$$2PbO + PbS = 3Pb + SO_2$$
$$\text{and } PbSO_4 + PbS = 2Pb + 2SO_2.$$

If the galena contains much silver, this is separated by crystallization and cupellation.

Properties.—Lead is a bluish-white metal, brilliant upon freshly cut surfaces, but soon tarnishes. It is soft and pliable, but not very malleable or ductile. Specific gravity, 11.37. It fuses at 334° C. (633° F.). It is a poor conductor of electricity, but a better conductor of heat.

When exposed to the air, it oxidizes slightly. It is not acted upon by pure water deprived of air, but, by the contact of air and water, it oxidizes to the hydroxide ($Pb(OH)_2$), which is slightly soluble in water. If the water contains carbon dioxide, carbonates, or sulphates, very little lead goes into solution, but it is coated with an insoluble layer of lead carbonate or sulphate. If the carbon dioxide be under pressure, as in soda water, the carbonate formed is somewhat soluble in the water.

The solvent action of water upon lead is increased, however, by the presence of nitrates and nitrites. These facts are of great practical importance, as lead pipes are very frequently employed for conducting potable waters.

Sulphuric and hydrochloric acids have but little effect on lead, especially if cold, owing to the insolubility of its sulphate and chloride. Nitric acid dissolves it readily. Zinc, tin, and iron precipitate this metal from its solution.

There are several useful alloys of lead. Alloyed with an equal part of tin, it fuses at 186° C. (366.8° F.) and is used for **soft solder**. Type-metal is an alloy of four or five parts of lead and one of antimony: the proportions vary considerably.

Lead Chloride ($PbCl_2$) separates as a white precipitate when hydrochloric acid is added to a concentrated solution of a lead salt. It is nearly insoluble in cold water, but dissolves in thirty parts of hot water, from which solution it crystallizes, on cooling, in white, shining needles. At a red heat it fuses to a horn-like mass.

Lead Iodide—Plumbi Iodidum (U. S., Br.), (PbI_2)—is precipitated from lead solutions by potassium iodide, as a bright yellow, crystalline powder. It is practically insoluble in cold water, but more soluble in boiling water, from which it crystallizes, on cooling, in beautiful, gold-colored, glistening crystals. An ointment of this salt is official. Exposed to light and moisture, it decomposes with the liberation of iodine.

Lead Oxide—Protoxide—Massicot—Litharge—Plumbi Oxidum (U. S., Br.), (PbO)—is prepared by heating lead, its carbonate or nitrate, in the air. Much of it is obtained as a bye-product, in the extraction of silver from galena. If it fuses, it constitutes **litharge**; if not, **massicot.** The former is a reddish-yellow or brown mass of rhombic scales; the latter is a yellow, amorphous powder, differing from litharge in color and texture, but not in composition.

Lead oxide has strong basic properties. It absorbs carbon dioxide from the air and imparts an alkaline reaction to water in which it dissolves as hydroxide. Like other strong bases, it saponifies fats when heated with them to form lead soaps, as **lead plaster.** It dissolves readily in nitric or hot acetic acid, with the formation of nitrate or acetate of lead. It fuses at a red heat. If fused in an earthen crucible, it attacks the crucible and forms a silicate, and thus perforates the crucible. When heated to 300° C. (572° F.) in contact with air, it is slowly oxidized to a bright red powder, **minium,** or red lead.

Plumboso-plumbic Oxide—Minium—Red Lead (Pb_3O_4) or ($2PbO.PbO_2$)—is prepared, as already stated, by roasting litharge at a temperature of 300° C. (572° F.), and is used as a pigment and in the manufacture of glass. Its composition is probably expressed by the formula Pb_3O_4; or, as one molecule of the dioxide combined with two of the monoxide; or, as the lead salt of plumbic acid.

It is a brilliant red powder, of a specific gravity of 8.62. When strongly heated, or subjected to the action of reducing agents, it is converted into litharge. Nitric acid dissolves the monoxide, leaving the dioxide, the color changing to brown.

As occurring in commerce, it is frequently contaminated with oxides of iron or brickdust. It should dissolve in diluted nitric acid to which a little sugar has been added.

Lead Dioxide—Peroxide of Lead—Puce Oxide of Lead—Binoxide of Lead—Plumbic Anhydride—may be prepared by dissolving the monoxide out of minium with diluted nitric acid, or by the action of chlorine upon lead carbonate suspended in water.

It is a dark, reddish-brown powder, insoluble in water; specific gravity 8.903 to 9.190. Heat drives off half its oxygen, converting it into the monoxide. It is therefore, when heated, a valuable oxidizing agent.

Plumbic Acid is formed as crystalline plates at the positive electrode, when alkaline solutions of the lead salts are subjected to electrolysis.

With the alkaline hydroxides, lead dioxide dissolves to form well defined but unstable **plumbates.** Potassium plumbate may be obtained in cubic crystals by dissolving the hydroxide in potassium hydroxide, and cooling the solution. It is decomposed by water.

Lead Nitrate—Neutral Lead Nitrate—Plumbi Nitras (U. S., Br.), ($Pb(NO_3)_2$)—is obtained by dissolving lead or its oxides in an excess of nitric acid.

$$PbO + 2HNO_3 = Pb(NO_3)_2 + H_2O.$$

It forms anhydrous octahedral crystals, soluble in two parts of water at 15° C. (59° F) and 0.7 part at 100° C. (212° F.). At a red heat, it melts and is decomposed into PbO, NO_2, and oxygen.

Lead Sulphate ($PbSO_4$) occurs in the mineral **Anglesite** in rhombic crystals, isomorphous with barium sulphate. It is produced by the double decomposition between a sulphate and a soluble lead salt.

$$Pb(NO_3)_2 + Na_2SO_4 = PbSO_4 + 2NaNO_3.$$

It is insoluble in water, but readily soluble in concentrated sulphuric acid. The commercial acid always contains it.

Lead Carbonate ($PbCO_3$) occurs as **Cerussite. Plumbi Carbonas** (U. S. P.) has the composition $(PbCO_3)_2 . Pb(OH)_2$ It may be produced by double decomposition between a lead salt and a soluble carbonate, or by passing carbon dioxide through a neutral solution of a lead salt. **White lead** is usually prepared, commercially, by treating thin sheets of lead with acetic acid and then exposing the acetate to carbon dioxide. The lead, rolled into sheets, is placed in earthen jars containing a small quantity of vinegar at the bottom, but not in contact with the lead. Great numbers of the jars after being thus charged, are buried in stable manure or spent tan bark. By the decomposition of the bark or manure, considerable carbon dioxide and heat are produced. The heat volatilizes a portion of the vinegar, which, acting upon the lead, produces the acetate ($Pb(C_2H_3O_2)_2$). The carbon dioxide acting upon the acetate converts it into a basic or hydro-carbonate of lead having the formula:—

$$(PbCO_3)_2\ Pb(OH)_2, \text{ or } PbO—HCO_3—Pb—CO_3—PbO—H,$$

and acetic acid, which acts upon a fresh portion of the lead. After the lapse of a considerable time about six weeks, the pile is taken down, the sheets are taken out, and the carbonate detached from them by passing them through rollers, or by pounding. The white powder is then ground with oil and sent into the market as "**White Lead.**"

White lead is largely used in oil painting, forming a part of all but the darkest colors. As it is poisonous, and is darkened by the action of hydrogen sulphide in the atmosphere, it is at present being more and more replaced by **zinc white** (ZnO) and **permanent white** ($BaSO_4$).

Lead Sulphide (PbS) occurs in the mineral **galena.** It is precipitated, as a black powder, from a solution of lead salts by hydrogen sulphide, or alkaline sulphydrates. The native sulphide is bluish-gray and has a metallic lustre. Sp. gr. 7.58. The sulphide obtained by precipitation has a sp. gr. of 6.924. It is insoluble in dilute acids.

Lead Acetate — Salt of Saturn — Sugar of Lead — Plumbi Acetas (U. S., Br.), ($Pb(C_2H_3O_2)_2).3H_2O$—is prepared by dissolving litharge in acetic acid; or by exposing lead to the action of acetic acid and air, evaporating and crystallizing. It forms large oblique rhombic prisms, having a sweetish, metallic taste. It dissolves in 2.3 parts of water at 15° C. (59° F.), and in 21 parts of alcohol, forming solutions which react acid upon test paper. On exposure to the air, the crystals effloresce upon the surface and are partly converted into carbonate. Several subacetates, or basic acetates, are known. The only one requiring mention is that having the formula, approximately, of $Pb_2O(C_2H_3O_2)_2$. This is the chief constituent of **Liq. plumbi subacetatis** (U. S., Br.) **or Goulard's extract,** which is obtained by boiling a solution of the neutral acetate with lead monoxide in fine powder. When exposed to the air, this solution absorbs CO_2 and becomes milky from the formation of lead carbonate.

Lead Chromate ($PbCrO_4$) is formed by precipitating lead nitrate or acetate with potassium chromate.

$$Pb(NO_3)_2 + K_2CrO_4 = PbCrO_4 + 2KNO_3.$$

It is used as a pigment, under the name of **chrome yellow.** Recently, its fraudulent use as an artificial coloring agent in manufactured food products has been discovered. It is insoluble in water, but soluble in strong alkalies.

Physiological Action of Lead.—All of the compounds of lead that are soluble, and those that are themselves insoluble but that are readily convertible into soluble compounds by the action of air, water, or the digestive fluids, are poisonous.

The chronic form of lead poisoning, **painter's colic**, is very common, and is produced by the continuous absorption of small quantities of the metal or its compounds, either by the skin, lungs, or the stomach. Although metallic lead is inert, its absorption will cause symptoms of poisoning from its being converted within the body into poisonous compounds. Some of the methods by which it may be introduced are: the drinking of water that has been in contact with the metal; the use of food, tobacco, etc. that has been wrapped in tin-foil containing lead; the drinking of beer or other beverages that have been kept in pewter vessels; and the handling of the metal, its salts, or its alloys by artisans. Almost all of the commoner compounds of lead may give rise to chronic poisoning. Probably the carbonate is the cause of more cases in painters, artists, manufacturers of paint, and persons sleeping in freshly painted apartments, than any other lead compound.

Acute lead poisoning is comparatively rare and is not often fatal. It is generally caused by the ingestion of a single large dose of the acetate, subacetate, carbonate, or red lead.

When it occurs, magnesium sulphate should be given, as it forms an insoluble lead sulphate.

If the metal be once absorbed, it is eliminated slowly, as it tends to become fixed by combination with the albuminoids of the body. This compound is rendered soluble by potassium iodide. It is eliminated by the urine, perspiration, and bile.

On account of the many ways in which it may be introduced, great caution is necessary in drawing conclusions from traces of lead found in the body after death.

The Remaining Metals of Group IV. are titanium, zirconium, cerium, and thorium. Of these the only one that has found use in medicine is cerium.

Cerium is a somewhat rare metal found in a number of minerals as a silicate, more especially in **cerite.** The element may be obtained by the electrolysis of cerous chloride. It resembles iron in most of its physical properties. Like iron, it forms two series of compounds.

The oxalate $Ce_2(C_2O_4)_3 + 9H_2O$ is used in medicine, and is prepared by precipitating cerous chloride with ammonium oxalate. It is a white powder, permanent in the air, odorless, tasteless, insoluble in water or alcohol, but soluble in hydrochloric acid. On heating the salt it decomposes, leaving a reddish yellow residue of Ce_2O_3.

GROUP I.—THE ALKALI METALS.

1. **Lithium**,	7	4. **Rubidium**,	85
2. **Sodium**,	23	5. **Cæsium**,	133
3. **Potassium**,	39	6. (**Ammonium**), NH_4	$=18$

The metals of this group present a great similarity in their chemical and physical properties. Exposed to the air, they all oxidize readily. They decompose water violently, with the formation of strong basic hydroxides which dissolve in the excess of water. The hydroxides thus formed are called **caustic alkalies** (caustic potash, caustic soda); hence the name, alkali metal. Nearly all of the salts of these metals are soluble, and most of them, when in solution, turn red litmus blue. They form but one chloride, one iodide, and one bromide.

LITHIUM.

$Li = 7$.

Lithium occurs widely distributed in nature, but in small quantities. It is found in some mineral springs and in the ashes of many plants, chiefly that of tobacco and beet. It is usually obtained by separating it from its chloride by electrolysis. It is silver-white in color, and decomposes water at ordinary temperatures. It is the lightest of the solid elements, and floats upon naphtha. Sp. gr. 0.589. It fuses at 180° C. (356° F.), and burns in air with an intense red light. Its salts closely resemble those of sodium.

Lithium Chloride ($LiCl$) crystallizes at ordinary temperatures, in regular, anhydrous octahedra; below 10° C. (50° F.), however, with two molecules of water. It is very deliquescent.

Lithium Bromide — Lithii Bromidum (U. S. P.), (LiBr)—is obtained by decomposing lithium sulphate with potassium bromide; or, by neutralizing a solution of hydrobromic acid with lithium carbonate. It crystallizes in deliquescent needles. Soluble in 0.6 part of water at 15°C. (59° F.) and 0.3 parts of boiling water. Very soluble in alcohol and ether.

Lithium Oxide (Li_2O) is a white solid, formed by burning lithium in dry oxygen. It slowly dissolves in water, forming the hydroxide, LiOH.

Lithium Carbonate—Lithii Carbonas (U. S. P.), (Li_2CO_3)—is obtained by fusing a native silicate called **lepidolite,** with barium sulphate and carbonate, and potassium sulphate. It is then extracted with water, and precipitated with sodium carbonate. It is a white, odorless powder, of a strongly alkaline taste, soluble in 80 parts of water at 15° C. (59° F.), and in diluted acids with copious effervescence. It unites readily with uric acid, forming a soluble lithium urate. It is said that 250 parts of lithium carbonate, at a temperature of 38° C. (100.4° F.), will dissolve almost 1000 parts of uric acid. This property renders it of value in diminishing the deposit of uric acid formed in gout, and in dissolving uric acid **calculi.**

Lithii Benzoas ($LiC_7H_5O_2$) (U. S. P.) is a light, white powder, having a faint benzoin-like odor, and a sweetish taste. It is soluble in 4 parts of water and in 12 parts of alcohol. Its aqueous solution has a faintly acid reaction upon litmus paper.

Lithium Citrate ($Li_3C_6H_5O_7$) (U. S. P.) is a white, odorless, deliquescent powder readily soluble in water, almost insoluble in alcohol. It is made by double decomposition between Li_2CO_3 and citric acid.

$$3Li_2CO_3 + 2H_3C_6H_5O_7 = 2Li_3C_6H_5O_7 + 3CO_2 + 3H_2O.$$

Lithium Salicylate ($LiC_7H_5O_3$) (U. S. P.) is made by double decomposition between lithium carbonate and salicylic acid.

$$Li_2CO_3 + 2HC_7H_5O_3 = 2LiC_7H_5O_3 + CO_2 + H_2O.$$

A white, deliquescent, odorless powder, having a sweetish taste. It is very soluble in water and alcohol.

SODIUM (Natrium).

Na = 23.

Occurrence.—This metal occurs widely distributed, being found in sea-water and in rock salt, as the chloride, in many native silicates, and also as borax and glauber salt.

Preparation.—It was formerly obtained by a process which depends upon the reduction of the carbonate by carbon. An intimate mixture of the two substances was prepared by charring the tartrate of sodium in an iron retort. The temperature was then raised to redness, when the sodium was reduced, distilled off, and condensed in flattened receivers.

$$Na_2CO_3 + C_2 = Na_2 + 3CO.$$

It is also manufactured by heating sodium hydroxide to about 800° C. (1472° F.) with iron carbide, when the sodium distils over and is condensed.

$$6NaOH + FeC_2 = 2Na_2CO_3 + Fe + 3H_2 + Na_2.$$

It is now generally prepared by the electrolytic decomposition of fused sodium hydroxide, according to the following reaction:

$$2NaOH = Na_2 + H_2 + O_2.$$

Properties.—Sodium is a soft, silver-white metal, resembling potassium, but less easily oxidized. On exposure to the air it becomes slowly coated with a brownish-yellow layer, and should be kept under naphtha. It fuses at 95.6° C. (204° F.), and volatilizes at a white heat, the vapor burning with a bright yellow flame. Sp. gr. 0.972. It is characterized by its affinity for oxygen, decomposing water at ordinary temperatures, liberating hydrogen, and forming sodium hydroxide, NaOH.

$$Na_2 + 2H_2O = 2NaOH + H_2.$$

Sodium Chloride—Common Salt—Sodii Chloridum (U. S., Br.), (NaCl)—is found very abundant in nature. It is deposited, in the solid form, as rock salt, in almost all parts of the globe; in solution, it is found in all natural waters, and to the extent of 2.7 to 3.2 per cent. in sea water; it also exists in most animal and vegetables tissues. It is formed in a great number of chemical reactions. Its most important source is the deposits of rock salt, from which it is mined: it is also obtained by the evaporation of sea water or saline spring waters. It crystallizes from water in translucent cubes. It fuses at a red heat, and volatilizes at a white heat. Hot water dissolves but little more than cold: 100 parts of water at 0° C. (32° F.) dissolve 36 parts of the salt, and at 100° C. (212° F.), 39 parts. A saturated solution, therefore, contains 36 per cent. sodium chloride. The ice obtained from dilute solutions is nearly free from NaCl. On account of a slight admixture of magnesium salts, most specimens of common salt will deliquesce: the perfectly pure salt, however, is not hygroscopic.

Sodium Bromide (Na Br) (U. S. P.) is formed, together with sodium hypobromite, by the action of bromine upon a cold solution of sodium hydroxide. The hypobromite is converted into bromate upon evaporating the solution to dryness.

$$3Br_2 + 6NaOH = 5Na\,Br + NaBrO_3 + 3H_2O.$$

The mixture of Na Br and Na BrO_3, is then heated with charcoal, which converts the Na BrO_3 into Na Br.

$$5Na\,Br + Na\,BrO_3 + 3C = 6Na\,Br + 3CO.$$

It crystallizes in anhydrous cubes, and is soluble in 1.13 parts of water at 20° C. (68° F.), and in 0.5 at 100° C. (212° F.). It contains 77.67 per cent. of bromine.

Sodium Iodide (NaI) (U. S. P.) is made by the action of iodine upon a hot solution of sodium hydroxide.

$$3I_2 + 6Na\,OH = 5NaI + NaIO_3 + 3H_2O.$$

The solution is evaporated, and the salts are then heated in contact with charcoal, and the $NaIO_3$ reduced to NaI.

$$5NaI + NaIO_3 + 3C = 6NaI + 3CO.$$

It crystallizes in cubes without water, and is soluble in 0.56 part of water at 20° C. (68° F.), and in 0.32 at 100° C. (212° F.). It contains 84.66 per cent. of iodine.

Oxides.—Two are described—Na_2O, and Na_2O_2. The first of these is a white powder, formed by the oxidation of the metal in dry air. It is very deliquescent, soon liquefying in air. The peroxide, Na_2O_2, is a grayish-white mass, obtained by burning sodium in a current of oxygen. They both unite with water with great energy.

Sodium peroxide has recently come into use as a bleaching and oxidizing agent. It contains about 20 per cent. of available oxygen. When thrown into water sodium hydroxide and oxygen are produced.

$$2Na_2O_2 + 2H_2O = 4NaOH + O_2.$$

When thrown into a solution of a dilute acid, hydrogen dioxide is produced.

$$Na_2O_2 + 2HCl = 2NaCl + H_2O_2.$$

It is employed as an oxidizing agent in the laboratory, and occasionally, in acid solutions, as a disinfectant.

Sodium Hydroxide—Sodium Hydrate—Caustic Soda—Soda (U. S. P.) ($NaOH$)—is usually obtained by boiling a solution of sodium carbonate with calcium hydroxide.

$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH.$$

The resulting solution, after filtering, is evaporated to dryness, dissolved in alcohol, again evaporated, fused in a silver vessel, and cast into sticks. This product is usually labeled **caustic soda, by alcohol.** It is a white, opaque, brittle, crystalline mass, or in dry white pencils, fusing below redness: sp. gr. 2.00. It dissolves readily in water, the solution being known as **soda lye** in the arts, and in pharmacy as **liquor sodæ** (sp. gr. of latter 1.059). This solution attacks glass; hence, the necks and stoppers of bottles containing it should be coated with paraffin. When exposed in the air, sodium hydroxide attracts water and carbon dioxide, liquefies, and is converted into the carbonate.

Sodium Sulphate—Neutral Sodium Sulphate—Glauber's Salt—Sodii Sulphas (U. S. P.)—**Sodæ Sulphas** (Br.) ($Na_2SO_4.10H_2O$)—occurs native in deposits; also in solution in mineral waters. It is a by-product in the manufacture of sodium chloride from sea water and brine, and in several manufacturing industries. It is prepared by the decomposition of common salt with sulphuric acid.

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

Sodium sulphate crystallizes, at ordinary temperatures, with ten molecules of water, in large, colorless, monoclinic prisms, which effloresce in the air, losing all of their water. If heated to 33° C. (91.4° F.) they liquefy in their own water of crystallization, and at higher temperatures become anhydrous. At 12° C. crystals may be obtained having the formula $Na_2SO_4.7H_2O$.

The following curious action of the solution of Glauber's salt may also be noticed. If the solution, saturated at 33° C. (91.4° F.), be cooled down to the ordinary temperature, and even far below, no separation of crystals occurs, although the salt is very much less soluble at lower temperatures than at 33° C. (91.4° F.). This formation of a **supersaturated solution** is common to many salts, though not to so marked a degree as in the case of Glauber's salt. This supersaturated solution may be agitated, and still no crystals form. But, if it be gently touched with a glass rod or some other solid body, the entire mass will at once become crystallized.

Hydrogen-Sodium Sulphate—Acid Sodium Sulphate—Sodium Bisulphate ($NaHSO_4$)—is obtained by the action of an excess of sulphuric acid upon sodium sulphate, or sodium chloride.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$

It crystallizes in long, four-sided prisms. It fuses readily, and at higher temperatures, loses water and is converted into the pyrosulphate, $Na_2S_2O_7$. It is very soluble in water, giving an acid solution.

Sodium Thiosulphate—Sodium Hyposulphite ($Na_2S_2O_3.5H_2O$)—is prepared by boiling the sulphite with sulphur.

$$Na_2SO_3 + S = Na_2S_2O_3.$$

Sodium hyposulphite forms large monoclinic prisms, which contain 5 molecules of water, and is slightly deliquescent in the air. It is used as a reducing agent, decolorizing an iodine solution with the formation of sulphuric acid and sodium iodide.

The **Sulphite—Sodii Sulphis** (U. S. P.) ($Na_2SO_3.7H_2O$)—is prepared by saturating one-half of a solution of Na_2CO_3 with sulphurous oxide and adding the other half. The SO_2 converts the carbonate into the hydrogen sodium sulphite, $HNaSO_3$.

$$Na_2CO_3 + H_2O + 2SO_2 = 2NaHSO_3 + CO_2.$$

This salt reacts with sodium carbonate to produce the sulphite.

$$2HNaSO_3 + Na_2CO_3 = 2Na_2SO_3 + H_2O + CO_2.$$

Sodium Bisulphite—Sodii Bisulphis (U. S. P.) ($HNaSO_3$)—is official. It is made by passing SO_2 into a solution of sodium carbonate, evaporating and crystallizing.

Sodium Carbonate—Soda—Neutral Carbonate of Soda—Sal Soda—Washing Soda—Sodii Carbonas (U. S. P.)—**Sodæ Carbonas** (B. P.) ($Na_2CO_3.10H_2O$)—is the most important of the sodium compounds, for industrial purposes. It occurs abundantly in nature, in the so-called sodium seas (in Egypt, and the Caspian Sea), and is contained in the ashes of many sea plants, chiefly the algæ. The principal supply is sodium chloride, from which it is manufactured according to a method devised by Leblanc in 1808. By this method the sodium chloride is first converted into the sulphate by warming with sulphuric acid. This part of the process is called the **salt cake process**. The sulphate, when dried, is mixed with charcoal and calcium carbonate, and strongly heated. Two reactions take place during this process: **First,** the carbon reduces the sodium sulphate to sulphide.

$$Na_2SO_4 + C_2 = Na_2S + 2CO_2.$$

Second, the sodium sulphide and calcium carbonate react to form calcium sulphide and sodium carbonate. This is known as the **soda ash process.**

$$Na_2S + CaCO_3 = CaS + Na_2CO_3.$$

The high temperature also converts a portion of the calcium carbonate into calcium oxide and carbon dioxide. The products of this fusion, known as **black ball soda,** are, therefore sodium carbonate, calcium sulphide, and calcium oxide. The black ball is broken up and lixiviated with hot water, which dissolves out the sodium carbonate; this solution is evaporated, and crude **soda ash,** or **soda** of commerce, results.

Of late years another process, known as Solvay's, or the ammonia method, has largely replaced that of Leblanc. In this process, a strong solution of sodium chloride is treated at the same time with ammonia gas and carbon dioxide.

$$NaCl + NH_3 + CO_2 + H_2O = NaHCO_3 + NH_4Cl,$$

forming the sparingly soluble sodium bicarbonate and the freely soluble ammonium chloride. The sodium bicarbonate is then converted into the carbonate by heat. The carbonate is also largely made by the **Cryolite Process.** Cryolite is a mineral found in great abundance in Greenland. It is a double fluoride of aluminum and sodium $(NaF)_6 . Al_2F_6$.

This is heated with lime (CaO), which decomposes it, forming calcium fluoride and aluminate of sodium.

$$(NaF)_6 . Al_2F_6 + 6CaO = 6CaF_2 + (Na_2O)_3 . Al_2O_3.$$

The aluminate of sodium is then dissolved out with water, and carbon dioxide passed through the solution.

$$(Na_2O)_3 . Al_2O_3 + 3H_2O + 3CO_2 = 3Na_2CO_3 + Al_2(OH)_6.$$

The $AL_2(OH)_6$ is precipitated, and the sodium carbonate is crystallized out of the solution.

At ordinary temperatures, sodium carbonate crystallizes in large rhombic crystals containing 10 molecules of water, which effloresce in dry air. It is soluble in water most freely at 38° C. (100.4° F.). Its solutions have an alkaline reaction. When the crystals are calcined at a dull red heat, they disintegrate, give off their water of crystallization, and form a white powder, the **sodii carbonas exsiccata** of the U. S. P. 100 parts of H_2O dissolve 10 parts of this anhydrous carbonate at 0° C. (32° F.), and 138 parts at 38° C. (100.4° F.).

Hydrogen Sodium Carbonate–Acid Sodium Carbonate—Sodium Bicarbonate—Sodii Bicarbonas (U. S. P.)—**Sodæ Bicarbonas** (Br. P.), ($NaHCO_3$)—is found in many mineral waters. It is produced by the ammonia process described above, and by the action of carbon dioxide upon sodium carbonate.

$$Na_2CO_3 + CO_2 + H_2O = 2NaHCO_3.$$

It forms small, rectangular prisms, which are anhydrous, but dissolve in ten or eleven parts of water. Its solutions are nearly neutral to test paper. By heating the solid, or boiling its solutions, it gives off carbon dioxide and is converted into the carbonate.

Sodium Phosphates.—These are three in number. They are less soluble and crystallize more easily than the potassium salts of phosphoric acid.

The **tri**-sodium phosphate, or **basic** phosphate ($Na_3PO_4.12H_2O$), is made by saturating 1 molecule of phosphoric acid with 3 molecules of sodium hydroxide. It crystallizes in six-sided prisms with $12H_2O$, and is soluble in 5.1 parts of water at 15.5° C. (59.9° F.). Its solution is alkaline to test paper.

Hydrogen Disodium Phosphate — Disodium Phosphate—Neutral Sodium Phosphate—Sodii Phosphas (U. S. P.)—**Sodæ Phosphas** (Br. P.), ($Na_2HPO_4.12H_2O$)—is more stable than the other phosphates, and is the one generally employed in medicine and in laboratories. It may be prepared by treating phosphoric acid with sodium hydroxide to feeble alkaline reaction. Below 30° C. (86° F.) it crystallizes in large, rhombic prisms, with 12 aq.: at 33° C. (91.4° F.) it crystallizes with 7 aq. The salt with 12 aq. effloresces in air, losing 5 aq.; that with 7 aq. does not. Both are freely soluble in water, and show a faintly alkaline reaction.

Monosodium Phosphate—Acid Sodium Phosphate ($NaH_2PO_4.H_2O$)—crystallizes in rhombic prisms with 1 molecule of water, and is acid in reaction. At 100° C. (212° F.) it loses its water of crystallization, and at about 250° C. (482° F.) forms **sodium pyrophosphate—sodii pyrophosphas** (U. S. P.), ($Na_4P_2O_7$ $10H_2O$). It occurs as colorless, translucent prisms, permanent in the air, and having a slightly alkaline reaction.

It is soluble in 12 parts of water, and insoluble in alcohol. When this salt is heated to a bright red heat the **metaphosphate** ($NaPO_3$) is formed.

$$Na_2H_2P_2O_7 = 2NaPO_3 + H_2O.$$

Sodium Nitrate—Chili Saltpetre—Sodii Nitras (U. S. P.), ($NaNO_3$)—is found native in extensive deposits in Peru. It crystallizes in rhombohedra, which closely resemble cubes; hence, it is called cubic saltpetre. It is deliquescent, and is, therefore, not adapted for the manufacture of gunpowder. It has a cooling, saline, somewhat bitter taste. It is more readily soluble in water than potassium nitrate, which, in other respects, it quite closely resembles. It is used in the manufacture of nitric acid, and also as a fertilizer.

Sodium Borates.—Six are known. The only one of importance is the **Disodium Tetraborate—Sodium Pyroborate—Borax—Tincal—Sodii Boras** (U. S. P.), ($Na_2B_4O_7.10H_2O$)—which is found native in some of the lakes of Thibet, from which country it was formerly imported. The principal source now is the borax lake in California.

It may be prepared artificially by boiling boric acid with sodium carbonate. Boric acid is found in the lagoons of Tuscany. This is the present source. Borax crystallizes in large, hexagonal prisms, with 10 molecules of H_2O, or in regular octahedra with $5H_2O$. The former variety effloresces in dry air; the latter is permanent. Both dissolve in 16 parts of cold, and 0.5 part of boiling water, forming a solution that has a feebly alkaline reaction. Upon heating, both salts puff up considerably, lose their water, and form a white, porous mass (**burned borax**), which finally fuses to a transparent glass. In the fused state, it will dissolve many metallic oxides, forming clear glasses, which often show a characteristic color on cooling; thus, copper oxide gives a blue, and chromic oxide an emerald green glass. Borax is used in this way as a blowpipe test for certain metals.

It is this property of dissolving oxides of the metals that renders borax useful in welding and soldering metals. In these operations it is used to remove the oxide, or rust, from the surfaces of the metals to be united.

Sodium Hypochlorite ($NaClO$).—An aqueous solution of this salt is known as **Liq. Sodæ Chloratæ** (U. S. P.), (Br.)—**Labarraque's solution**. It may be prepared by decomposing a solution of chlorinated lime with sodium carbonate.

$$CaO_2Cl_2 + CaCl_2 + 2Na_2CO_3 = 2NaCl + 2NaClO + 2CaCO_3.$$

The solution contains sodium hypochlorite, sodium chloride and sodium carbonate.

To make a litre of the solution, 75 grms. of chlorinated lime is triturated well with about 400 c. c. of water, the solution filtered, and the residue washed with 100 c. c. of cold water. To this solution is then added a solution of 150 grms. of sodium carbonate in 300 c. c. of hot water. The turbid mixture may then be filtered, or set aside to allow the $CaCO_3$ to settle, and the clear supernatent liquid decanted off. The solution should be kept in well-stoppered bottles, and protected from the light to prevent too rapid deterioration. It should contain 2.6 per cent. by weight of available chlorine. It yields up its chlorine readily, thus acting as an efficient disinfecting and deodorizing agent.

Sodium Chlorate—Sodii Chloras (U. S. P.), ($NaClO_3$)—may be made by a double decomposition between $KClO_3$ and sodium bitartrate, $NaHC_4H_4O_6$, forming cream of tartar, $KHC_4H_4O_6$, and $NaClO_3$.

Sodii Benzoas (U. S. P.), ($NaC_7H_5O_2$)—is made by adding benzoic acid to a solution of sodium bicarbonate, as long as effervescence continues.

$$HC_7H_5O_2 + NaHCO_3 = NaC_7H_5O_2 + CO_2 + H_2O.$$

It is a white powder, having a very faint, benzoin-like odor, and a sweet astringent taste. It is used as an antifermentative agent.

Sodii Arsenas (U. S. P.), ($Na_2HAsO_4 + 7H_2O$,)—is made by heating to fusion arsenous acid, with exsiccated sodium carbonate and sodium nitrate. Pyroarsenate of sodium is formed, which is converted into sodium arsenate when dissolved in water.

Sodii Sulphocarbolas (U. S. P.), ($NaSO_3C_6H_4OH$).—When crystallized carbolic acid is dissolved in strong sulphuric acid, sulphocarbolic acid is formed. When this is treated with barium carbonate, sulphocarbolate of barium is formed in solution. If this solution is now treated with sodium sulphate, a precipitate of barium sulphate will form and sulphocarbolate of sodium may be crystallized out from the solution.

Sodii Acetas (U S. P.), ($NaC_2H_3O_2 + 3H_2O$), may be made by neutralizing acetic acid with bicarbonate of sodium.

$$NaHCO_3 + HC_2H_3O_2 = NaC_2H_3O_2 + CO_2 + H_2O.$$

Physiological Effects of the Sodium and Potassium Compounds.—The action of the halogen salts of these metals is generally that of the combined chlorine, bromine, or iodine.

parts at 0° C. (32° F.), and 0.2738 part more for every degree of increase of temperature.

Potassium Bromide—Potassii Bromidum (U. S. P., Br.), (KBr)—is generally obtained by dissolving bromine in a solution of potassium hydroxide; the bromate also produced in the reaction is converted into bromide by calcining the product with charcoal.

$$3Br_2 + 6KOH = 5KBr + KBrO_3 + 3H_2O.$$
$$5KBr + KBrO_3 + C_3 = 6KBr + 3CO.$$

It may also be prepared by acting upon ferrous bromide with potassium carbonate.

$$FeBr_2 + K_2CO_3 = FeCO_3 + 2KBr.$$

It has the general properties of the other haloid salts, and is used in photography and in medicine.

Potassium Iodide—Potassii Iodidum (U. S. P., Br.), (KI)—may be prepared, like the preceding, by using iodine instead of bromine, or by using ferrous iodide instead of bromide. It crystallizes in large, white, translucent cubes, salty in taste and permanent in the air. It dissolves to the extent of 100 parts in 73.5 parts of water at ordinary temperatures. Its aqueous solution dissolves iodine in large quantities, forming the **compound solution** of iodine (U. S. P.). It also dissolves many metallic iodides to form double iodides. Its medicinal effects are those of iodine. When employed in chronic poisoning by lead or mercury, it is supposed to unite with the metals in the blood or tissues to form soluble iodides, and thus pass them out by the urine. There is an ointment of KI official, containing 12 per cent. of KI.

Potassium Fluoride (KF)—Its aqueous solution attacks glass. Is not of much importance to the medical student.

Potassium Cyanide—Potassii Cyanidum (U. S. P.), (KCN)—may be obtained either by saturating potassium hydroxide with hydrocyanic acid, or by heating potassium ferrocyanide. It is a white, amorphous, deliquescent mass, easily fusible, and smelling of cyanogen. Its solution is very poisonous. Its effects upon the economy are uncertain, but are probably those of hydrocyanic acid. In case of poisoning by it, the stomach should be evacuated and the antidotes of hydrocyanic acid given.

Ferrocyanide and Ferricyanide—see page 216.

Potassium with **Oxygen—Potassium Oxide** (K_2O)—results from the direct oxidation of potassium, by simply exposing thin strips of the metal to dry air, or by the action of potassium upon the hydroxide.

$$2KOH + K_2 = 2K_2O + H_2.$$

It is a white, deliquescent, caustic powder, uniting readily with water to form the hydroxide.

Potassium Hydroxide—Potassium Hydrate—Caustic Potash—Potassa (U. S. P.), **Potassa Caustica** (Br.), (KOH)—is prepared by the reaction of potassium carbonate upon calcium hydroxide (slaked lime).

$$K_2CO_3 + Ca(OH)_2 = CaCO_3 + 2KOH.$$

After these substances have been boiled together, the solution is allowed to settle. The clear liquid is then poured off, evaporated, and the residue fused in a silver dish. The fused mass is then cast into sticks. This is called **potash by lime,** and is not pure. To render it purer, it is dissolved in alcohol, the solution evaporated to dryness, the residue again melted and cast in silver moulds. This product is **potash by alcohol,** and is free from the chloride and other potassium salts. It is a white, opaque, brittle solid, usually met with in the form of cylindrical sticks, but sometimes in lumps. It has a specific gravity of 2.1. It fuses quite easily, and, at high temperatures, volatilizes undecomposed. It is freely soluble in water; less so in alcohol. The solutions have a marked alkaline reaction, saponify fats, and are strongly caustic. Exposed to the air, it absorbs water and carbon dioxide, and is changed into the carbonate. In watery solution it is largely used as a reagent in chemical analysis. It dissolves chlorine, bromine, iodine, sulphur and phosphorus. It decomposes the ammoniacal salts, liberating ammonia; it also decomposes the salts of many of the metals, with the formation of a potassium salt and a hydroxide or oxide of the metal.

Potassa cum Calse (U. S. P.) is made by rubbing together, in an iron mortar, lime and potassa so as to form a powder. It is to be kept in a well-stoppered bottle.

Liquor Potassæ is a 5 per cent. aqueous solution of potassium hydroxide.

Potassium Chlorate—Potassii Chloras (U. S. P.), ($KClO_3$).—When a hot, concentrated solution of potassium hydroxide is treated with chlorine gas, the following reaction occurs:—

$$6KOH + 3Cl_2 = 5KCl + KClO_3 + 3H_2O.$$

deliquescent powder, freely soluble in water, the solution having a caustic taste and an alkaline reaction.

Potassium carbonate is largely made, from the native chloride, by the Leblanc process. A very pure potassium carbonate is made from argols (impure bitartrate of potassium) by calcination.

$$2KHC_4H_4O_6 + 5O_2 = K_2CO_3 + 7CO_2 + 5H_2O.$$

Potassium Bicarbonate—Hydropotassium Carbonate—Potassii Bicarbonas (U. S. P.)—**Potassæ Bicarbonas** (Br.), ($KHCO_3$). When carbon dioxide is passed through a concentrated solution of potassium carbonate, it is absorbed and potassium bicarbonate is produced.

$$K_2CO_3 + H_2O + CO_2 = 2KHCO_3.$$

This salt crystallizes in oblique, rhombic prisms, of the monoclinic system. It dissolves in 3 to 4 parts of water: the solution is faintly alkaline, but not caustic. The substance that is still extensively used in some parts of the country in baking, under the name of **saleratus**, is this, or the corresponding sodium salt. It "raises" the bread by the action of heat in setting free the carbon dioxide, and leaving potassium (or sodium) carbonate, which, by its strongly alkaline reaction, may cause digestive disturbances.

Sulphides.—Five are known: K_2S, K_2S_2, K_2S_3, K_2S_4, and K_2S_5; also a sulphydrate, KSH. The latter is prepared by the action of hydrogen sulphide upon potassium hydroxide.

$$KOH + H_2S = KSH + H_2O.$$

The **Pentasulphide—Liver of Sulphur—Potassa Sulphurata** (U. S. P.)—**Potassa Sulphureta** (Br.), (K_2S_5)—is obtained by fusing potassium carbonate with an excess of sulphur. It decomposes readily, and treated with hydrochloric acid it gives off hydrogen sulphide.

Potassium Sulphate—Dipotassium Sulphate—Potassii Sulphas (U. S. P.)—**Potassæ Sulphas** (Br.), (K_2SO_4)—is found in the Stassfurth mines, in plant ashes, and in solution in mineral waters. It is obtained by the action of sulphuric acid upon potassium chloride, as a by-product in some chemical manufacturing processes.

$$2KCl + H_2SO_4 = K_2SO_4 + 2HCl.$$

It crystallizes without water, in small, rhombic prisms, of a bitter, salty taste, and is soluble in 10 parts of water at ordinary temperatures.

Hydropotassium Sulphate — Monopotassium Sulphate—Acid Potassium Sulphate ($KHSO_4$)—is formed as a by-product in the manufacture of nitric acid from potassium nitrate; crystallizes in large, rhombic tables, and is very readily soluble in water. At about 200° C. (392° F.) it fuses, loses water, and is converted into the pyrosulphate ($K_2S_2O_7$).

Sulphites.—Three are known: K_2SO_3, $KHSO_3$, and $K_2S_2O_5$. **Potassium Sulphite—Neutral Potassium Sulphite—Potassium Sulphis** (K_2SO_3).—This salt crystallizes in oblique rhombic octahedra, which dissolve readily in water, and have a sulphurous odor. When in solution, if exposed to the air, it absorbs oxygen, and is converted into the sulphate.

Potassium Acetate—Potassii Acetas (U. S. P.)—**Potassæ Acetas** (Br.), ($KC_2H_3O_2$)—exists in the juices of plants. It is obtained by neutralizing acetic acid with potassium carbonate or bicarbonate. It crystallizes in shining needles, is deliquescent, and very soluble in water.

Oxalates.—Three are known to exist: **Potassium Oxalate—Neutral Oxalate** ($K_2C_2O_4 + Aq.$), formed by saturating oxalic acid with potassium carbonate. **Hydropotassium Oxalate — Monopotassium Oxalate — Binoxalate of Potash** ($2KHC_2O_4$). **Potassium Quadroxalate** ($KHC_2O_4 \cdot C_2O_4H_2 + 1\ Aq.$). A mixture of these two salts is known as **salt of lemon,** or **salt** of **sorrel,** and is used for bleaching straw and to remove ink stains. In appearance it closely resembles Epsom salt, and has caused many cases of oxalic acid poisoning, being taken by mistake for that salt.

Tartrates.—Potassium Tartrate—Soluble Tartar—Neutral Tartrate of Potash —Potassæ Tartras (Br.), ($K_2C_4H_4O_6$)—is a white, crystalline powder, very soluble in water; soluble in 240 parts of alcohol. **Hydropotassium Tartrate—Cream of Tartar—Potassii Bitartras** (U. S. P.), **Potassæ Bitartras** (Br.), ($KHC_4H_4O_6$). A brown-red, crystalline crust is obtained from the bottom and sides of wine casks after fermentation has taken place. This is known in commerce as **argol,** or **crude tartar,** and is composed in great part of potassium bitartrate, with tartrate of lime and coloring matter.

The argol is boiled with water, or heated in a closed digester by superheated steam. The latter process renders the calcium tartrate insoluble and separates it almost completely from the cream of tartar, which goes into solution. The solution thus obtained is allowed to cool and crystallize; the crystals are redissolved in hot water, treated with animal charcoal, to remove coloring matters, filtered, and again crystallized. The product of this process is almost chemically pure acid potassium tartrate.

It crystallizes in hard, opaque, rhombic prisms, very sparingly soluble in water, still less so in alcohol. Its solution is acid to the taste, and to litmus paper. It is largely used in baking, combined with sodium bicarbonate, the two substances reacting upon each other to form Rochelle salt, with the liberation of carbon dioxide. **Baking powders** are extensively used at present, instead of yeast, for raising cake, biscuits, etc. In all of them the action depends upon the decomposition of sodium bicarbonate by some salt having an acid reaction or by a weak acid.

In addition to the bicarbonate, and the starch added to preserve them, many of them contain either tartaric acid, alum, or acid phosphate of calcium, instead of cream of tartar.

Some of the reactions that take place to set free the carbon dioxide are the following :—

$$1.\ \underset{\substack{\text{Potassium}\\\text{Bitartrate.}}}{KHC_4H_4O_6} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{NaHCO_3} = \underset{\substack{\text{Sodio-potassium}\\\text{Tartrate.}}}{NaKC_4H_4O_6} + \underset{\text{Water.}}{H_2O} + \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{CO_2}.$$

$$2.\ \underset{\substack{\text{Aluminum potassium}\\\text{Alum.}}}{Al_2(SO_4)_3.K_2SO_4} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{6NaHCO_3} = \underset{\substack{\text{Potassium}\\\text{Sulphate.}}}{K_2SO_4} + \underset{\substack{\text{Sodium}\\\text{Sulphate.}}}{3Na_2SO_4} +$$

$$\underset{\substack{\text{Aluminum}\\\text{Hydroxide.}}}{Al_2H_6O_6} + \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{6CO_2}.$$

$$3.\ \underset{\substack{\text{Calcium}\\\text{Biphosphate.}}}{CaH_4(PO_4)_2} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{2NaHCO_3} = \underset{\substack{\text{Hydro-calcium}\\\text{Phosphate.}}}{CaHPO_4} + \underset{\substack{\text{Sodium}\\\text{Phosphate.}}}{Na_2HPO_4} +$$

$$\underset{\text{Water.}}{2H_2O} + \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{2CO_2}.$$

A good powder may be made by intimately mixing two parts of cream of tartar with one of sodium bicarbonate, and adding a little flour or starch.

Sodium Potassium Tartrate—Rochelle Salt—Potassii et Sodii Tartras (U. S. P.), ($NaKC_4H_4O_6 . 4H_2O$),—is prepared by boiling acid potassium tartrate with sodium carbonate.

$$2KHC_4H_4O_6 + Na_2CO_3 = 2KNaC_4H_4O_6 + CO_2 + H_2O.$$

It forms large, transparent, prismatic, slightly efflorescent crystals, soluble in 1.4 parts of cold water, saline, and slightly bitter to the taste, and neutral in reaction.

Potassium Antimonyl Tartrate — Tartrated Antimony — Tartar Emetic—Antimonii et Potassii Tartras (U. S.), $2(SbOKC_4H_4O_6.).H_2O$—is prepared by boiling a solution of cream of tartar with antimonious oxide. Its crystals are transparent, right rhombic octahedra, efflorescing in the air. It is quite soluble in water, the solution having a nauseating, metallic taste. It is poisonous, and has even caused death when applied to the skin as a local irritant and vesicant.

RUBIDIUM and CÆSIUM.

$Rb = 85.3.$ $Cs = 132.6.$

These rare metals were discovered in 1860 by Bunsen and Kirchoff, by means of the spectroscope. Both elements were named from the color of their lines in the spectrum (**rubidius**, dark red, and **cæsius**, sky blue). They occur in small quantities, widely distributed, often accompanying potassium. With platinum chloride they form double chlorides ($PtCl_4.2RbCl$). Rubidium iodide and rubidium ammonium bromide have been used in medicine.

Rubidium Iodide (RbI) occurs as colorless crystals, readily soluble in water, and having most of the physical properties of potassium iodide, for which it is substituted as a remedy, in doses of 2 grains three times daily.

Rubidium Ammonium Bromide ($RbBr.3NH_4Br$) occurs as a white crystalline powder, readily soluble in water and possessing a cooling, saline taste. It has been used in epilepsy.

AMMONIUM COMPOUNDS.

Ammonium (NH_4).—This radical has only a hypothetical existence, never having been isolated. But there are many reasons for believing that it does actually exist in combination in the ammonium compounds, and that in these compounds it plays the rôle of a metal resembling sodium and potassium. The oxide of this radical has not been separated.

Ammonium Chloride—Ammonium Muriate—Sal-Ammoniac—Ammonii Chloridum (U. S. P., Br.), (NH_4Cl)—was formerly obtained by the dry distillation of camel's dung. At present it is prepared chiefly by saturating the ammonia water from gas works with hydrochloric acid, evaporating the solution to dryness, and subliming the residue in iron vessels. Prepared in this way, it is a compact, tough, fibrous mass, which dissolves in 2.7 parts cold and one part boiling water. It crystallizes from its solution in small octahedra or cubes, of a sharp, salty taste, and a neutral reaction. When heated, it volatilizes without fusing; at the same time a dissociation into NH_3 and HCl occurs, but on cooling, these products recombine into ammonium chloride.

This salt exists in minute quantities in the gastric juice of various animals. The urine, saliva, and tears also contain some ammonium compound, which is said to be the chloride.

Ammonium Bromide—Ammonii Bromidum (U. S. P., Br.), ($(NH_4)Br$.)—may be prepared by direct combination of ammonia and hydrobromic acid, or by decomposing ferrous bromide with aqua ammoniæ,

$$FeBr + 2NH_4OH = Fe(OH)_2 + 2NH_4Br,$$

or by subliming a mixture of potassium bromide and ammonium sulphate.

$$2KBr + (NH_4)_2SO_4 = 2NH_4Br + K_2SO_4.$$

It forms a white, granular powder, or large prisms, which turn yellow on exposure to the air, and possess a saline, pungent taste and neutral reaction. It dissolves in 1.5 parts of water, and volatilizes without decomposition.

Ammonium Iodide—Ammonii Iodidum (U. S. P.), (NH_4I)—is prepared by the action of hydriodic acid upon ammonia, or by the double decomposition of potassium iodide and ammonium sulphate.

$$2KI + (NH_4)_2SO_4 = 2NH_4I + K_2SO_4.$$

It may also be prepared by adding ammonia water to a solution of ferrous iodide.

$$FeI_2 + 2NH_4OH = Fe(OH)_2 + 2NH_4I.$$

It forms cubic crystals, which are deliquescent and are soluble in 0.60 part of water. They decompose in the air, turning yellow and emitting the odor of iodine.

Ammonium Hydroxide (NH_4OH) is believed to exist in solution in the ordinary aqua ammoniæ, although, when the attempt is made to isolate it, decomposition ensues. (See page 169.) It is made by warming ammonium chloride or sulphate with calcium hydroxide.

$$(NH_4)_2SO_4 + Ca(OH)_2 = CaSO_4 + 2NH_4OH.$$

Aqua Ammoniæ Fortior (U. S. P.) has a sp. gr. of 0.901, and contains 28 per cent. NH_3.

Aqua Ammoniæ (U. S. P.) is of sp. gr. 0.960, and contains 10 per cent. NH_3.

Ammonium Carbonates.—Three are known: **Ammonium Carbonate—Neutral Ammonium Carbonate** ($(NH_4)_2CO_3$)—may be prepared as a crystalline powder by passing ammonia gas through a concentrated solution of the sesquicarbonate. Exposed to the air, it splits up into ammonia and the acid carbonate, NH_4HCO_3.

$$(NH_4)_2CO_3 = NH_4HCO_3 + NH_3.$$

Hydro-ammonium Carbonate—Acid Ammonium Carbonate (NH_4HCO_3)—is obtained when a solution of ammonium hydroxide or sesquicarbonate is saturated with carbon dioxide. It forms large, rhombic crystals, which are quite soluble in water. At 60° C. (140° F.) it is decomposed into ammonia and carbon dioxide.

Ammonium Sesquicarbonate—Sal-Volatile—Ammonii Carbonas (U. S. P.) ($NH_4HCO_3 + NH_4NH_2CO_2$)—is the commercial carbonate of ammonia, and was formerly prepared by the dry distillation of bones, horns, and other animal substances. It is at present prepared by heating a mixture of ammonium chloride or sulphate with calcium carbonate, and condensing the volatilized product. As seen by the formula, it is a mixture of the acid carbonate and the carbamate, though probably when fresh it consists of the pure neutral carbonate. So prepared, it sublimes as a white, transparent, hard mass, having an ammoniacal odor and an alkaline reaction. On exposure to the air, it gives off ammonia and carbon dioxide. The carbonates of ammonia are very unstable.

Ammonium Nitrate — Ammonii Nitras (U. S. P.), (NH_4NO_3) —is prepared by neutralizing nitric acid with ammonium hydroxide or carbonate. It crystallizes in flexible, six-sided prisms, without water; dissolves in 0.5 part water at 15° C. (59° F.), and fuses at 165° C. (329° F.). When heated to 210° C. (410 F.), it decomposes, with the formation of nitrous oxide or laughing gas, and water.

$$(NH_4)NO_3 = N_2O + 2H_2O.$$

Ammonium Sulphate—Neutral Ammonium Sulphate —Ammonii Sulphas ($(N_4H)_2SO_4)$—may be obtained by saturating the ammonia water from gas works with sulphuric acid. It forms rhombic crystals, soluble in two parts of cold and one part of hot water. At 140° C. (284 F.) it fuses, and at higher temperatures it decomposes into ammonia, nitrogen, water, and ammonium sulphite.

Ammonium Acetate ($(NH_4)C_2H_3O_2$) is formed when acetic acid is saturated with ammonia water, or ammonium carbonate. It is seldom seen except in solution in water. The aqueous solution is used in medicine as the **Liq. Ammonii Acetatis**, or **Spirit of Mindererus**, which contains about 7 per cent. of the salt.

Other salts in use are the **benzoate, phosphate, and valerianate,** all white crystalline salts. The benzoate, $NH_4C_7H_5O_2$, and the Valerianate, $NH_4C_5H_9O_2$, are official.

Ammonium Sulphide ($(NH_4)_2S$) is a white, crystalline solid, formed by mixing dry hydric sulphide and ammonia at a low temperature—18° C. (about 0 F.). It is usually prepared by mixing the sulphydrate with sulphur. It dissolves sulphur and the sulphides of arsenic, tin, and antimony, and is used in analysis for this purpose.

Ammonium Sulphydrate (NH_4SH) is prepared by saturating a solution of ammonium hydroxide with hydrogen sulphide (sulphuretted hydrogen). It is colorless at first, but becomes yellow on exposure, from decomposition. It is used in laboratories as a reagent. Acids decompose both these sulphides, setting free sulphur.

Action on the Economy.—In large quantities, or by prolonged use, ammonia and its salts are poisonous. Ammonia, if inhaled, acts as a severe irritant upon the air passages, causing dyspnœa, pain, suffocation, and even death. The treatment in cases of poisoning consists in neutralizing the alkali with diluted acids; or, in using the vapor of acetic or diluted hydrochloric acid as an inhalation. Two drachms of a strong solution of ammonium hydroxide have proved fatal.

COPPER (Cuprum).

$Cu = 63.6.$

Occurrence.—This metal occurs in the free state in large masses, or crystallized in cubes and octahedra. It is found in the vicinity of Lake Superior, in China, Japan, Sweden, and in the Urals. Its most important ores are: cuprite (Cu_2O), malachite, and azurite (basic carbonates), chalcocite (Cu_2S), and chalcopyrite, or copper pyrites ($CuFeS_2$).

Preparation.—The mixed copper ores are first roasted in the air, by which process a portion of the copper, if a sulphide, is converted into oxide. This is then roasted with a silica flux and carbon. By this process the iron sulphide is converted into a silicate, and is drawn off with the slag. After several repetitions of this process the so-called **copperstone** is obtained. This contains both the sulphide and oxide. By repeated roasting and heating, the copper oxide reacts upon the sulphide, and metallic copper results. Some poor ores are first treated with sulphuric acid, and the resulting sulphate is then treated with scrap iron, which precipitates the copper in the metallic state. Chemically pure copper is obtained by electrolysis, or by heating the pure oxide in a stream of hydrogen.

Properties.—Copper is a red metal by reflected light, while thin leaflets transmit a green light.

It is soft, ductile, and tenacious; a good conductor of heat and electricity; specific gravity 8.914 to 8.952. In dry air it undergoes no change, but in moist air it gradually becomes coated with a thin layer of green basic carbonate. When heated, it oxidizes to black cupric oxide (CuO). Hot sulphuric, nitric, and hydrochloric acids dissolve it, with liberation of sulphur dioxide, nitrogen dioxide, and hydrogen, respectively. With organic acids it forms soluble salts in the presence of air and moisture; hence, acid fruits should not be kept in copper vessels.

Cuprous Compounds.—These are very unstable, absorb oxygen, and are converted into cupric compounds.

If the formulæ $CuCl$, CuI, Cu_2O, and Cu_2S are correct, copper in the cuprous compounds would appear, like silver, to be univalent. It has never been determined, however, whether these formulæ really express the true molecules. Copper compounds are not volatile, and we have no means of ascertaining the size of the molecule. As has already been stated, most chemists believe that in the cuprous compounds copper is bivalent, and that they contain the group Cu_2'', whose valence is always two.

Cuprous Chloride—Subchloride, or Protochloride ($CuCl$ or Cu_2Cl_2)—is produced, together with cupric chloride, by igniting metallic copper in chlorine gas; by dissolving cuprous oxide in hydrochloric acid without contact of air; or by the action of many reducing agents upon solutions of cupric chloride. It is a heavy white powder, rapidly becoming green in the air, owing to the absorption of oxygen and the formation of cupric chloride $\left(\mathrm{Cu}\begin{array}{l}\diagup \mathrm{Cl}\\ \diagdown \mathrm{Cl}\end{array}\right)$. It dissolves in concentrated hydrochloric acid, but not in water. With carbon monoxide it forms a crystallizable compound. Its hydrochloric acid solution is used in gas analysis to absorb this gas.

Cuprous Iodide (Cu_2I_2) is precipitated, together with iodine, from soluble cupric salts by potassium iodide.

$$2CuSO_4 + 4KI = 2K_2SO_4 + Cu_2I_2 + I_2.$$

On dissolving out the iodine with ether, the iodide is left as a gray insoluble powder.

Cuprous Sulphide — Subsulphide, or Protosulphide (Cu_2S)—occurs in the mineral **chalcocite,** as soft, fusible, gray crystals; also in many double sulphides, among which the most important is the double sulphide of copper and iron, or **copper pyrites.**

Cuprous Oxide—Suboxide (Cu_2O)—occurs in nature as **cuprite.** It is obtained artificially by boiling an alkaline solution of grape sugar and copper sulphate. It precipitates as a bright red powder. (Fehling's and Trommer's tests.) The hydroxide ($Cu_2(OH)_2$) is precipitated by the alkalies, from hydrochloric acid solutions of Cu_2Cl_2, as a yellow powder.

Cupric Compounds. Cupric Chloride ($CuCl_2$) is formed by dissolving cupric oxide or carbonate in hydrochloric acid. From aqueous solutions it crystallizes in bright green, rhombic needles with $12H_2O$. It is readily soluble in water and alcohol. When heated, it parts with its water, and forms anhydrous cupric chloride, which at a red heat gives off chlorine.

$$2CuCl_2 + \text{heat} = Cu_2Cl_2 + Cl_2.$$

Cupric Bromide resembles the chloride. The iodide is not known.

Cupric Oxide—Binoxide—Black Oxide (CuO)—is prepared by heating copper turnings to redness in the air, or by calcining the nitrate. It forms a black amorphous powder, readily reduced to the metallic state by heated charcoal, hydrogen, or the alkaline metals. If heated in the presence of organic substances, it oxidizes them completely, and is thereby reduced to the metal. It is used in organic analysis for this purpose.

Cupric Hydroxide ($Cu(OH)_2$) is formed as a voluminous bluish-white precipitate when sodium or potassium hydroxide is added to a solution of a copper salt. When heated, even under water, it becomes dehydrated, and changed to black cupric oxide.

Copper oxide and hydroxide dissolve in ammonium hydroxide, forming a dark-blue solution. This solution is often used as a solvent for cellulose, from which acids precipitate it again.

Cupric Sulphate—Blue Vitriol—Blue Stone—Cupri Sulphas (U. S. P., Br.), ($CuSO_4\ 5H_2O$). This is the only official salt of copper. It may be prepared, first, by roasting chalcocite; second, from the water of certain copper mines; third, by exposing copper, moistened with diluted sulphuric acid, to the air; fourth, by dissolving copper oxide in hot, concentrated sulphuric acid.

$$CuO + H_2SO_4 = CuSO_4 + H_2O.$$

It forms large, blue, triclinic crystals, which dissolve in 2.6 parts of water at 15° C. (59° F.), and in 0.55 part of water at 100° C. (212° F.). It loses four molecules of water at 100° C. (212° F.), while the fifth separates above 200° C. (392 F.), leaving a white amorphous powder, which readily takes up water, and in so doing resumes its blue color. Solutions of copper salts have a blue color, acid reaction, and metallic, styptic taste.

Ammonium hydroxide added to a solution of copper sulphate, precipitates a bluish-white cupric hydroxide, which dissolves in an excess of the alkali, forming a deep blue solution consisting of

ammonio-sulphate of copper, or **cupric-tetrammonium sulphate,** $Cu(NH_3)_4SO_4.H_2O$. This solution is used as a test for arsenic. Alcohol precipitates from this solution long, right rhombic prisms of cupric-tetrammonium sulphate, which are very soluble in water.

Cupric sulphate also enters into the **alkaline cupric tartrate solution—Fehling's Solution.**

Cupric Carbonates.—The neutral carbonate ($CuCO_3$) is not known. When alkaline carbonates are added to solutions of copper salts, the basic carbonate separates as a green precipitate, having the formula $CuCO_3.2Cu(OH)_2$. This salt occurs in nature, especially in Siberia, as **malachite.** Another basic salt, **tricupric carbonate,** or **sesquicarbonate** of copper, is the beautiful blue mineral, **azurite.**

Copper Arsenite — Scheele's Green, is prepared by adding a solution of sodium or potassium arsenite to a solution of a copper salt. It is a green powder, composed of copper arsenite and copper hydroxide. It is insoluble in water, but soluble in ammonium hydroxide or the mineral acids. It is exceedingly poisonous, but is often used as a pigment to color wall papers, toys, and even confectionery.

Schweinfurt Green — Mitis Green, or Paris Green ($Cu(C_2H_3O_2)_2 + 3(CuO_4As_2)$), is the commonest and most dangerous of the cupro-arsenical pigments. It is prepared by adding a concentrated solution of cupric acetate to a boiling solution of arsenous acid. It is an insoluble, green, crystalline powder, decomposed by prolonged boiling in water, by aqueous solutions of the alkalies, and by the mineral acids. It is soluble in ammonium hydroxide.

Cupric Acetate ($Cu(C_2H_3O_2)_2$) is formed by the decomposition of a solution of copper sulphate by lead acetate. It separates in large, bluish-green, prismatic crystals, with one molecule of H_2O, which it loses at 140° C. (284° F.). The dry salt, when heated to 250° C. (482° F.), decomposes with the liberation of glacial acetic acid.

Basic Acetates. — Verdigris — Cupric Subacetate is a complex mixture of copper acetate and hydroxide. It is prepared by exposing to the air piles composed of alternate layers of grape skins and copper plates, and after some time removing the bluish-green coating from the plates.*

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* The term verdigris is now often popularly applied to the green carbonates, hydroxides, or salts of organic acids, which accumulate on the surface of copper.

Copper Pigments.—The most important are: **Brighton Green,** a mixture of copper acetate and chalk; **Brunswick Green,** originally an impure chloride, but now generally a mixture of the carbonate and chalk; **Mountain Green,** or **Mineral Green,** is a native green carbonate of copper, sometimes containing orpiment. **Neuwieder Green** is a mixture of mineral green or Schweinfurt green with gypsum, or barium sulphate. **Green Verditer** is a mixture of the basic carbonate, the oxide, and chalk.

Physiological Action of Copper.—Until recently, toxicologists were universally of the opinion that all the copper salts are poisonous. Of late, however, this has been considerably modified. Most of the copper compounds have an irritant, local action if brought into contact with the gastric or intestinal mucous membrane, causing vomiting of greenish matter, cramps, etc. On the other hand, there are numerous instances in which severe illness, characterized by nervous and other constiutional symptoms, have followed the use of food that has been in contact with imperfectly tinned copper vessels. Some such cases have proven fatal. It has been conclusively shown, however, that **pure** and non-irritating copper compounds may be taken in considerable quantity without any bad results.

Copper sulphate is frequently used as an astringent in medicine, and has been recommended in cholera and dysenteric troubles. This salt may be taken in considerable doses, with only an emetic effect. Cases of acute poisoning are not common, but some are recorded. Chronic poisoning is occasionally seen in those who work in copper, characterized by colicky pains, emaciation, impaired digestion, diarrhœa, and often a catarrhal cough. In most cases there is a green line on the margin of the gums. Copper is very likely to become contaminated with arsenic; and it is possible that some of the cases of reported copper poisoning ought to be attributed to arsenic. The organic salts of copper seem to be more poisonous than the inorganic. Canned peas, pickles, and other fruits are often contaminated with copper, and the manufacturers have frequently been punished by fines; but there exists a difference of opinion as to the dangers of copper in such goods. As long, however, as there is a chance for doubt, sanitary authorities should prohibit its use. The chemist must remember that most articles of food contain traces of copper.

The treatment of cases of irritant copper poisoning should consist in the exhibition of milk, white of egg, and other albuminous substances, with which the copper salt may form an inert compound. Emesis should be induced if it has not taken place spontaneously.

SILVER (Argentum).

$Ag = 108$.

Occurrence.—This metal occurs in nature in combination with chlorine, bromine, iodine, sulphur, arsenic, copper, antimony, etc. The principal localities in which it is found are the western United States, Mexico, Hungary, and Saxony.

It is found native to some extent. The lead ore, **galena**, furnishes much silver.

Preparation.—For a description of the elaborate processes by which silver is extracted from its ores, the student is referred to works on metallurgy. As usually obtained by these processes the metal is not pure, but is contaminated to a greater or less extent by copper and other metals. To obtain it chemically pure, the ordinarily occurring silver is dissolved in nitric acid, and from this solution of the nitrates, silver is precipitated as chloride by hydrochloric acid or common salt. The silver chloride thus obtained may be reduced by fusion with sodium carbonate, or by the action of zinc or iron in the presence of water and HCl.

$$2AgCl + Zn = ZnCl_2 + 2Ag.$$

Properties.—It is a brilliant white metal. Its sp. gr. is 10.47 to 10.54. It is tolerably malleable, soft, very ductile, and is the best known conductor of heat and electricity. It does not oxidize in the air, but frequently tarnishes in ordinary atmospheres from the presence of minute quantities of hydrogen sulphide, which blacken it. It unites directly with the members of the **halogen group**. It dissolves in hot, strong sulphuric acid, to form the sulphate.

$$Ag_2 + H_2SO_4 = Ag_2SO_4 + H_2.$$

It is more easily attacked by nitric acid, which dissolves it with great readiness, even when largely diluted.

$$6Ag + 8HNO_3 = 6AgNO_3 + 4H_2O + N_2O_2.$$

In order to give it the necessary hardness for use in the arts, it is usually alloyed with copper. Coin silver contains 10 per cent. of copper, in the U. S., France, Germany and Austria.

Silver Chloride ($AgCl$) is formed whenever hydrochloric acid or a soluble chloride is added to aqueous solutions of silver salts, as a curdy, white precipitate.

$$AgNO_3 + HCl = AgCl + HNO_3.$$

It is insoluble in acids, but soluble in solutions of alkaline chlorides, hyposulphites, and cyanides, and freely so in ammonium hydroxide. It may be crystallized from ammoniacal solutions in large regular octahedra.

Silver Bromide ($AgBr$) precipitates from solutions of silver salts on the addition of hydrobromic acid or a soluble bromide.

$$AgNO_3 + HBr = AgBr + HNO_3.$$

With the exception of not being quite so soluble in ammonium hydroxide, it very closely resembles silver chloride.

Silver Iodide (AgI)—**Argenti Iodidum** (U. S. P.)—differs from the chloride and bromide in its yellow color, and insolubility in ammonia. Actinic rays of light change the color of silver chloride, bromide, and iodide, first to violet, then brown, and finally black. The bromides and iodides are more sensitive to light than the chloride.

Silver Oxide—Silver Monoxide—Silver Protoxide—Argenti Oxidum (U. S. P., Br.), (Ag_2O)—is precipitated from solutions of soluble silver salts by sodium or potassium hydroxide, as a dark brown, faintly alkaline powder, slightly soluble in water.

$$2AgNO_3 + 2KOH = Ag_2O + 2KNO_3 + H_2O.$$

It has strong basic properties. It readily gives up its oxygen when heated. It should not be triturated with substances which are readily oxidizable, or combustible, as it is easily reduced. When the solution in ammonium hydroxide is evaporated, there separate black crystals of an explosive compound ($Ag_2O.2NH_3$), which, when dry, explode on the slightest disturbance.

Silver Suboxide (Ag_4O) and **Silver Peroxide** (AgO, or Ag_2O_2) are also known.

Silver Nitrate—Argenti Nitras (U. S. P., Br.), ($AgNO_3$)—is prepared by dissolving pure silver in a somewhat diluted nitric acid, evaporating, recrystallizing, and washing with strong nitric acid. It separates in large anhydrous plates, soluble at ordinary temperatures in one part of water or 26 parts of alcohol, and forms colorless solutions.

On exposure to light, in the presence of organic matter, its solutions turn black, and deposit metallic silver. It has been proposed to use this reaction as a test for organic matters in potable waters. Chlorine and iodine decompose it, with the liberation of anhydrous nitric acid, and the formation of a chloride or an iodide. When fused and cast into cylindrical moulds, it forms the **Argenti nitras fusus** (U. S. P.), **lapis infernalis,** or **lunar caustic** of pharmacy. **Argenti nitras dilutus** (mitigated caustic) is an official preparation, made by melting together 30 parts of silver nitrate, and 60 parts of potassium nitrate, and casting in suitable moulds.

This salt is also used in photography, in the manufacture of hair-dyes, marking ink, and in the silvering of glass.

Silver Cyanide—Argenti Cyanidum (U. S. P.), ($AgCN$) —precipitates from silver nitrate solutions as a white, curdy mass, on the addition of potassium or sodium cyanide. It is freely soluble in an excess of the reagent. It is also soluble in ammonium hydroxide and sodium hyposulphite, but is not affected by light. A solution of this compound in potassium cyanide is used as the plating bath in electro-plating with silver.

Silver Salts in Photography.—The property of undergoing reduction to the metallic state, by the action of light and organic matter, makes the silver salts useful in photography.

In taking a photograph, a negative is first prepared, as follows: A plate of glass, previously well cleaned, is evenly covered by floating over it a solution of collodion (a solution of **pyroxylin** in ether and alcohol) containing a small quantity of iodide or bromide of potassium, and then dried. On dipping the plate into a solution of silver nitrate, it becomes coated with a layer of silver iodide or bromide. After exposure in the camera, it is taken to the dark room and "**developed**" by pouring upon it a solution of pyrogallic acid, or ferrous sulphate, which reduces the silver salts to the metallic state on that portion of the plate that has been acted upon by light, and makes it opaque. In printing from this, a sheet of albuminized paper, previously floated upon a solution of silver nitrate and then dried, is placed behind the negative and exposed to a strong light. The same action takes place upon the paper; the lights upon the negative becoming dark upon the paper. The image is fixed by dissolving off the undecomposed silver with a solution of sodium hyposulphite.

GOLD (Aurum).

Au = 197.

Occurrence —Native gold occurs widely distributed, though in small quantities. It is sometimes found in the form of beautiful crystals, belonging to the cubical system, but generally as veins in quartz. It is also found in the beds of various rivers, in the form of a granular dust. This may be separated by simple washing, the simplest device being the "pan," which is a round dish of sheet iron, with sloping sides, about twelve or fourteen inches in diameter. This pan is about half filled with the mud and sand to be washed, and is held in a stream of water and rotated in such a way that the lighter material is carried away and the gold left When larger quantities are to be washed, the "cradle" is used. The gold dust so obtained, or the gold quartz which has been pulverized, is treated with mercury, which forms an amalgam with the gold. This amalgam is then placed in a retort and heated. The mercury distils over, leaving the gold behind.

Properties.—Gold is orange yellow by reflected light, and green by transmitted light, and is very ductile and exceedingly malleable. It fuses at 1200° C. (2192° F.), has a specific gravity of 19.36, and is a good conductor of heat and electricity. It retains its lustre even at high temperatures. It is not affected by any single acid or alkaline hydroxide. A mixture of nitric and hydrochloric acids readily dissolves it, forming a solution of the chloride. It combines directly with the halogens, phosphorus, antimony, arsenic and mercury. In handling bromine, care should be taken that its vapor, or the bromine itself, does not come in contact with rings or other gold jewelry, lest they be attacked.

Uses.—Gold preparations are not much used in medicine. It is extensively employed, however, in the manufacture of jewelry and for coinage. For either of these purposes it is too soft to be used alone, but is always alloyed with either copper or silver. In estimating the fineness of gold in jewelry, it is divided into twenty-four equal parts, called **carats.** The alloy is said to be of so many **carats** fineness, when it contains that number of twenty-fourths of pure metal. Eighteen-carat gold is, then, $\frac{18}{24}$ gold, and six carats base metal.

Aurous Chloride ($AuCl$) is a pale yellow, insoluble powder, formed by heating auric chloride to 200° C. (392° F.).

Auri et Sodii Chloridum ($AuCl_3 + NaCl$) is used in medicine. It is a yellow, deliquescent solid, having a saline, metallic taste and an acid reaction. It is soluble in water and alcohol.

Auri et Sodii Chloridum is not a chemical compound, but a mixture of auric chloride, $AuCl_3$, and sodium chloride, NaCl, in equal parts by weight. It is decomposed by heat, and metallic gold separates.

Auric Chloride—Gold Trichloride ($AuCl_3$)—occurs in deliquescent prisms, soluble in water, alcohol and ether. With phosphorus or reducing agents it is readily decomposed, with the separation of gold. When in solution, it gives, with stannous chloride, a beautiful purple, flocculent precipitate—**purple of Cassius**—which is used to ornament glass and porcelain. Auric chloride is used in photography for "toning." The silver print is placed in the gold solution, when metallic gold is deposited upon the silver picture, thus giving it a yellow tint or "tone."

Aurous Oxide (Au_2O) is a dark violet powder, formed by the action of potassium hydroxide upon aurous chloride. Hydrochloric acid changes it to auric chloride and gold.

Auric Oxide (Au_2O_3) is prepared by digesting magnesium oxide in a solution of auric chloride, decomposing the magnesium aurate with nitric acid, and drying the residue at 100° C. (212° F.). It is a dark-brown powder, which decomposes easily, and unites readily with positive oxides to form **aurates**, having the general formula $RAuO_2$. It will thus be seen, from its behavior with oxygen, that gold is either monad or triad.

GROUP II.—METALS OF THE ALKALINE EARTHS.

Beryllium, **Be** = 9.
Calcium, **Ca** = 40.
Strontium, **Sr** = 87.66.
Barium, **Ba** = 137.43.

The metals of this group are called metals of the alkaline earths, because their oxides resemble, on the one hand, the oxides of the alkali metals, and, on the other, the real earths (alumina, etc.). Like the potassium group, their properties and chemical energy increase gradually with their atomic weights. Their basic properties also become greater with their atomic weights. Thus, barium decomposes water more energetically, and oxidizes more readily than strontium or calcium. Barium hydroxide is likewise the strongest base. It is quite soluble in water. It fuses without decomposition, and absorbs carbon dioxide rapidly from the air. Calcium hydroxide possesses weaker basic properties, is difficultly soluble in water, and, when ignited, breaks up into water and calcium oxide. Strontium stands between barium and calcium. Thus, although these metals resemble the alkali metals, both in their free state and as hydroxides, they essentially differ from them in the insolubility of their carbonates and phosphates, and still more of their sulphates. Barium sulphate is insoluble in water and acids.

CALCIUM.

Ca = 40.

Occurrence.—This metal forms one of a class of elements most widely distributed in nature. Its carbonate (limestone, marble, and chalk), its sulphate (gypsum and alabaster), and its phosphate, fluoride, and silicate are common minerals.

Preparation.—Calcium may be obtained from the fused chloride by electrolysis; or, by heating calcium iodide with sodium, or calcium chloride with sodium and zinc.

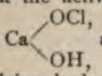
Properties.—It is a light-yellow, lustrous, ductile metal. It fuses at a red heat, does not sensibly volatilize, and burns in the air with a brilliant reddish-yellow light. It does not undergo oxidation in dry air, but in moist air covers itself with a layer of hydroxide. Its specific gravity is 1.577.

Calcium Chloride—**Calcii Chloridum** (U. S. P , Br.), ($CaCl_2$)— is prepared by the action of hydrochloric acid upon marble. It crystallizes with 6 molecules of H_2O, in large, six-sided prisms, which are bitter, deliquescent, and very soluble in water. If heated, it melts in its water of crystallization with some loss of water. About 200° C. (392° F.), it becomes anhydrous. The fused calcium chloride is the official salt. It is a white mass, slightly translucent, having a sharp, saline taste, but no odor. The dry salt is a white, porous mass, which fuses at a red heat and solidifies to a crystalline mass, which rapidly absorbs water, and is used as a drying agent for gases and liquids other than water. **Calcium iodide** and **bromide** are very similar to the chloride. The bromide ($CaBr_2$) is official.

Chloride of Lime — Chlorinated Lime — Bleaching Powder—Calx Chlorata (U. S., Br.)—is a mixture of calcium chloride ($CaCl_2$) and calcium hypochlorite ($Ca(ClO)_2$) with some water. The hypochlorite is the active principle. It is prepared by passing chlorine over slaked lime.

From the analogous action of chlorine upon sodium or potassium hydroxide, we may express the reaction in the case of calcium hydroxide by the following equation :—

$$2Ca(OH)_2 + 2Cl_2 = Ca(OCl)_2 + CaCl_2 + 2H_2O.$$

According to this equation, the completely chlorinated chloride of lime must contain 48.9 per cent. of chlorine, which is never the case, as a portion of the calcium hydroxide always remains unchanged. The exact constitution of chloride of lime is in doubt; but from more recent observations, it is believed by some that the active constituent of chloride of lime is a basic calcium hypochlorite  $\mathrm{Ca}{<}\genfrac{}{}{0pt}{}{\mathrm{OCl},}{\mathrm{OH},}$ and the following reaction takes place when chlorine acts upon calcium hydroxide :—

$$3Ca(OH)_2 + 2Cl_2 = 2CaO_2HCl + CaCl_2 + 2H_2O.$$

Calculating from this equation, completely saturated chloride of lime contains only 39 per cent. chlorine, which is found to be actually the case.

Others regard chloride of lime as a chloro-hypochlorite, having the graphic formula, $CaCl — O — Cl$, and formed according to the following reaction: $Ca(OH)_2 + Cl_2 = CaOCl_2 + H_2O$. When dissolved in water this compound, it is claimed, decomposes, giving CaO_2Cl_2 and $CaCl_2$. This idea of its composition seems to me improbable.

Chloride of Lime is a grayish-white, porous powder, having a bitter, acrid taste, and a chlorine-like odor. It is alkaline in reaction, soluble in cold, and decomposed by boiling water. It slowly decomposes in the air, the carbon dioxide liberating hypochlorous oxide. This decomposition is hastened by sunlight and heat.

$$Ca(ClO)_2 + CaCl_2 + 2CO_2 = 2CaCO_3 + 2Cl_2.$$

Diluted mineral acids decompose it very rapidly, with the liberation of chlorine.

$$Ca(ClO)_2 + CaCl_2 + 4HCl = 2CaCl_2 + 2H_2O + 2Cl_2.$$

The application of chloride of lime to bleaching and disinfecting purposes depends upon this production of free chlorine. The amount that will be set free by acids is called the **available chlorine,** which in good chloride of lime should be at least 25 per cent. The official **calx chlorata** should contain not less than 35 per cent.

Calcium Oxide—Lime—Calx (U. S., Br.), (CaO)—is obtained pure by igniting the carbonate or nitrate. On a large scale, it is prepared commercially by heating the natural carbonate (limestone or marble) in rude stone furnaces, called lime kilns. It is a grayish-white, amorphous solid, alkaline and caustic. Sp. gr. 2.3. It does not fuse at any temperature at our command. When the oxyhydrogen flame is thrown upon it, it becomes incandescent, and emits an extremely intense, white light (calcium, or Drummond light). It combines energetically with water to form the hydroxide, the process being known as **slaking**, and is attended with the evolution of much heat.

$$CaO + H_2O = Ca(OH)_2$$

It is used for making building mortar. When exposed to the air for some days, it absorbs moisture, becomes **air-slaked** and crumbles to a powder.

Calcium Hydroxide—Slaked Lime—Calcii Hydras (Br.), $Ca(OH)_2$—is a dry, white powder, odorless, and alkaline in reaction. It is slightly soluble in cold and less so in hot water. Exposed to the air, it absorbs carbon dioxide and forms the carbonate. Ordinary mortar is a mixture of slaked lime, water, and quartz sand. The hardening of mortar depends upon three causes: 1st. The natural evaporation of the water. 2d. The absorption of carbon dioxide from the air, and the formation of calcium carbonate.

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

3d. The action of the basic hydroxide upon the silicic acid of the sand, producing calcium silicate.

$$Ca(OH)_2 + SiO_2 = CaSiO_3 + H_2O.$$

This last reaction takes place slowly; hence the hardness of old mortars. Hydraulic mortar, or **cement**, contains calcium oxide, aluminum silicate, and quartz powder; its hardening depends principally upon the formation of calcium and aluminum silicates.

Lime Water—Liquor Calcis (U. S., Br.)—is a clear, saturated solution of calcium hydroxide in water.

The percentage of $Ca(OH)_2$ varies with the temperature. It contains about 0.17 per cent. at the ordinary temperature, but when the temperature rises the solution becomes weaker.

Cane sugar increases the solubility of calcium hydroxide, with which it forms a saccharate. The British **Liquor calcis sac-**

charatus is a solution of calcium hydroxide in a strong solution of cane-sugar.

Syrupus Calcis (U. S. P.) is an analogous preparation.

When lime-water contains an excess of the hydroxide, rendering it turbid, it is called milk of lime.

Calcium Carbide (C_2Ca) is prepared by heating in an electrical furnace an intimate mixture of coal tar and lime. The mass fuses and can be poured out of the crucible, and on cooling is found to be composed of carbon mixed with lustrous, dark-brown or black masses of calcium carbide. These masses are hard and brittle, giving a crystalline fracture. On exposure to moist air, it decomposes and loses its lustre. The most interesting property of C_2Ca is its decomposition when brought in contact with water.

$$\underset{\text{Calcium Carbide.}}{C_2Ca} + \underset{\text{Water.}}{H_2O} = \underset{\text{Acetylene.}}{C_2H_2} + \underset{\text{Calcium Oxide.}}{CaO}.$$

The acetylene produced is pure and burns with a smoky flame. When diluted with from 6 to 10 volumes of air, it gives a flame of great brilliancy and intensity. This compound is interesting because it can be cheaply made, and serves to bridge over the gap between inorganic and organic substances, and allows us to prepare, on a manufacturing scale, an organic compound from the elements.

Calcium Sulphate ($CaSO_4$) occurs very abundantly in nature as **gypsum,** in right rhombic prisms, combined with two molecules of water. The anhydrous salt forms the mineral **anhydrite.** It is very sparingly soluble in water At ordinary temperatures one part dissolves in 400 parts H_2O. Ground gypsum is used in the arts under the name of **terra-alba.** When heated to about 120° C. (248° F.), it parts with its water, becoming converted into an opaque white mass, which, when ground, is called **Plaster-of-Paris**.

Calcii Sulphas Exsiccatus (U. S. P.), (Dried Gypsum), contains about 95 per cent. of $CaSO_4$ and about 5 per cent. of water. It is prepared by heating pure native gypsum ($CaSO_4 . 2H_2O$) until about three-fourths of the water is expelled.

This powder, mixed with water, takes up two molecoles and hardens into a stone-like solid. Upon this property depends the usefulness of plaster for making moulds, figures, and immovable surgical dressings.

Calcium Phosphates—Tricalcic—Neutral—or **Bone Phosphate—Calcii Phosphas Præcipitatus** (U. S. P.)—

Calcis Phosphas (Br.), ($Ca_3(PO_4)_2$)—is found in rocks, and especially in the mineral **apatite,**

$$3Ca_3(PO_4)_2 + CaF_2,$$

and in soils, in guano, in the ash of plants, and in every tissue and fluid of animal bodies.

It may be prepared pure by dissolving bone ash in hydrochloric acid, filtering, and precipitating with ammonium hydroxide:

$$Ca_3(PO_4)_2 + 4HCl = CaH_4(PO_4)_2 + 2CaCl_2.$$

$$CaH_4(PO_4)_2 + 2CaCl_2 + 4NH_4OH = Ca_3(PO_4)_2 + 4NH_4Cl + 4H_2O.$$

Also, by double decomposition between calcium chloride and an alkaline phosphate. It is a gelatinous mass when first precipitated, but after drying, a white, amorphous powder. It is insoluble in water, but readily soluble in dilute acids, even acetic; also, in water charged with carbon dioxide. An impure tricalcium phosphate, prepared by burning bones, is known as **bone-ash.**

Dicalcium Phosphate, $Ca_2H_2(PO_4)_2$, separates as an amorphous insoluble precipitate, when disodium phosphate is added to a strong solution of calcium chloride mixed with a little acetic acid.

Monocalcium Phosphate—Acid Calcium Phosphate—Superphosphate of Lime, $CaH_4(PO_4)_2$—is found in brain tissue and in acid animal fluids. It is produced by the action of sulphuric or hydrochloric acid upon the first two phosphates, and is manufactured as a fertilizer, mixed with calcium sulphate, by decomposing bones with sulphuric acid.

$$Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_4(PO_4)_2 + 2CaSO_4.$$

At a temperature of 200° C. (392° F.) it splits up into calcium pyrophosphate, metaphosphoric acid, and water.

$$2Ca(H_2PO_4)_2 = Ca_2P_2O_7 + 2HPO_3 + 3H_2O.$$

When this mixture is ignited with charcoal, the metaphosphate is formed, and reduced to phosphorus and $Ca_3(PO_4)_2$.

Calcium Carbonate — Calcii Carbonas (U. S. P., Br.), ($Ca\,CO_3$)—is of exceedingly wide distribution in nature. It exists sometimes in enormous deposits, as limestone, marble, chalk, Iceland spar, and as the mineral basis of the corals, shells of the crustacea, mollusks, etc. Chalk is a comparatively pure, amorphous, calcium carbonate, made up of microscopic shells.

Calcium carbonate is nearly insoluble in pure water, but dissolves readily in water containing carbon dioxide. Hence, we find it dissolved in nearly all natural waters, as an acid—or bicarbonate ($CaH_2(CO_3)_2$), giving rise to temporary hardness. Boiling, agitation, or free exposure to the air may decompose this salt, and deposit the ordinary calcium carbonate. Upon this depends the formation of stalactites, boiler incrustations, and similar deposits.

Calcii Carbonas Præcipitatus (U. S. P.) is made by pouring together solutions of calcium chloride and sodium carbonate. Double decomposition takes place, and $CaCO_3$ is precipitated.

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

The white precipitate of calcium carbonate is filtered off, washed with water and dried. **Prepared chalk—creta præparata** (U. S., Br.)—is a native chalk, purified by **elutriation,** which consists in grinding the chalk in water, allowing the mixture to partially subside, decanting the upper portion, and collecting and drying the fine particles.

Calcium Oxalate (CaC_2O_4) is found in the juice of some plants and in the urine. It may be obtained, as a fine, white, crystalline powder, by adding any soluble oxalate to a soluble calcium salt dissolved in a neutral or alkaline solution,

$$(NH_4)_2C_2O_4 + CaCl_2 = 2NH_4Cl + CaC_2O_4.$$

It is insoluble in water and acetic acid, but soluble in the mineral acids. In many diseased conditions which produce deficient oxidation, or excessive production of acids (lung disease and acid dyspepsia), it occurs in the urine in considerable quantities, and gives rise to **oxaluria,** or the oxalic acid diathesis. This salt frequently forms calculi, which present irregular projections, and have received the name of mulberry calculi. Excessive saccharine diet, or excessive consumption of certain vegetables, as tomatoes, rhubarb, etc., increase the production and elimination of calcium oxalate.

Calcii Hypophosphis (U. S. P.), ($Ca(PH_2O_2)_2$) is made by boiling together calcium hydroxide and phosphorus until combination is complete, and phosphoretted hydrogen (PH_3) ceases to be evolved.

$$3Ca(OH)_2 + 2P_4 + 6H_2O = 3Ca(PH_2O_2)_2 + 2PH_3.$$

The solution is then filtered, evaporated, and granulated. It is generally obtained as a white granular powder, having no odor, but a nauseous, bitter taste.

Calx Sulphurata—Crude Calcium Sulphide (U. S. P.).—This is made by mixing together dried calcium sulphate and powdered charcoal, and heating to bright redness in a loosely-covered crucible, until the black color of the mixture has disappeared. It is a mixture containing about 60 per cent. of CaS, with $CaSO_4$ and carbon in varying proportions. It has a pale gray color, and a slight odor of H_2S.

Physiological Effects and Uses.—The calcium salts play an important part in the animal economy. The phosphates are found in every tissue and fluid of the body, but most abundant in the bones and teeth; the former containing from 55 to 59 per cent., and the latter, including the carbonate, 72 per cent. As the salts of lime are insoluble in alkaline fluids, various theories have been put forward to explain their state in the blood and other alkaline fluids. It seems certain that the calcium of blood serum does not exist as phosphate, but as some soluble salt or albumin compound, soluble in alkaline fluids. The calcium phosphate of the urine remains in solution as long as that fluid is acid, but separates as an amorphous or crystalline sediment as soon as it undergoes alkaline fermentation. Alkaline urine is always turbid. When taken internally, the calcium salts produce effects similar to those of sodium and potassium, but milder. They have a mild astringent effect.

STRONTIUM.

Sr = 87.6.

Strontium is rather sparingly found in nature. The principal minerals are **strontianite** ($SrCO_3$) and **celestite** ($SrSO_4$). It is a brass-yellow, lustrous metal, which resembles calcium in its properties, as also do its compounds. This element exhibits most of the properties of calcium and barium. Strontium may be made by decomposing the chloride by electricity. Its compounds impart a red tinge to the flame, and for this reason the nitrate is used as a constituent of red fires. The solubility of its sulphate stands between that of calcium and barium. It has been used in medicine as an alterative. Its salts are poisonous only in large quantities.

Strontium Chloride ($SrCl_2.6H_2O$).—This salt may be prepared by treating HCl with an excess of strontianite, and digesting the mixture for some time to allow the iron, aluminum, etc., to separate from the solution, which may then be drawn off and evaporated. On cooling, this concentrated solution deposits acicular crystals, having a bitterish taste. They are soluble in 1.8 parts of water, are soluble in alcohol and deliquesce in the air

Strontium Bromide—Strontii Bromidum, U. S. P. ($SrBr_2.6H_2O$).—This salt may be prepared by saturating hydrobromic acid with strontium carbonate,

$$2HBr + SrCO_3 = SrBr_2 + CO_2 + H_2O.$$

The clear solution is concentrated by evaporation and allowed to crystallize.

Strontium bromide occurs as deliquescent, colorless, odorless, transparent, hexagonal crystals, and having a bitter saline taste. It is soluble in 1.05 parts of water at 15° C. (59 F.). It is soluble in alcohol, but insoluble in ether. The crystals melt, when heated, and lose all their water. This salt, as well as all the salts of strontium, imparts an intense red color to the non-luminous flame. It is used in medicine in doses of one to 20 grms. per day.

Strontium Iodide—Strontii Iodidum, U. S. P. (SrI_2-$6H_2O$).—This salt is prepared by saturating hydriodic acid with strontium carbonate.

$$2HI + SrCO_3 = SrI_2 + CO_2 + H_2O.$$

The solution is then evaporated and allowed to crystallize.

Strontium iodide occurs as colorless, odorless, transparent, hexagonal plates having a bitterish saline taste. They deliquesce and turn yellow on exposure to the air. The crystals are soluble in 0.6 part of cold water, and are soluble in alcohol, and slightly so in ether. When heated they melt and gradually lose their water. At a red heat they decompose, giving off iodine and leaving a residue of strontium oxide. This salt is used in medicine.

Strontium Monoxide (SrO), **Strontium Dioxide** (SrO_2) and **Strontium Hydroxide** (SrO_2H_2) are known.

Strontium Nitrate ($Sr(NO_3)_2$), prepared by dissolving the carbonate in nitric acid, has been recommended in articular rheumatism. It occurs as colorless crystals, soluble in 5 parts of water and permanent in the air.

Strontium Phosphate ($Sr_3(PO_4)_2$), a white, tasteless powder sparingly soluble in water, **Strontium Acetate** ($Sr(C_2H_3O_2)_2$), **Strontium Carbonate** ($SrCO_3$) and **Strontium Sulphate** ($SrSO_4$) have been somewhat used as medicines.

Strontium Lactate—Strontii Lactas, U.S.P.($Sr(C_3H_5O_3)_2.3H_2O$).—This salt may be prepared by saturating a solution of lactic acid with $SrCO_3$. It is a white granular powder, or crystalline nodules, odorless, and having a slightly bitter, saline taste.

It is permanent in the air, and soluble in 4 parts of water at 15° C. (59° F.), and soluble in alcohol. It loses its water at 110° C. (230° F.). It has been used in renal diseases associated with albuminuria, and as a tænifuge.

It is given in 15 to 40 grain doses.

BARIUM.

$Ba = 137.2$.

Barium is found in nature in the form of **barite,** $BaSO_4$, and also as **witherite,** $BaCO_3$.

The element itself is not of interest to the medical student.

Barium Chloride ($BaCl_2 + Aq.$) is prepared by the action of hydrochloric acid upon the native carbonate, using an excess of the latter, and allowing the mixture to stand a few days to allow the iron and other metals to precipitate. It is used as a reagent for soluble sulphates, giving a white precipitate, insoluble in acids or water.

It has been used in medicine as an alterative and anthelmintic.

Barium Oxide—Baryta (BaO) —is obtained by calcining the nitrate. It is a grayish-white, caustic powder, fusible in the oxy-hydrogen flame. It unites with water, with the evolution of much heat, to form the hydroxide BaH_2O_2. This dissolved in water forms baryta water.

Barium Peroxide—Barii Dioxidum (U. S. P.), (BaO_2)—is a white powder decomposed by diluted acids, with the production of hydrogen peroxide. It is the only official compound of barium. It is made by heating the oxide to a red heat in the air or in oxygen. If the heat is raised too high, the oxygen which was at first absorbed is again given off.

$$2BaO + O_2 = 2BaO_2.$$
$$2BaO_2 = 2BaO + O_2.$$

This power of absorbing oxygen from the air, and giving it off again at a higher temperature, has been used in manufacturing oxygen.

It is also used for making hydrogen peroxide.

Barium Nitrate ($Ba(NO_3)_2$)—forms anhydrous, octahedral crystals of the regular system, soluble in water, and used as a constituent of pale-green theatre fires.

Barium Sulphate ($BaSO_4$) **Heavy Spar** or **Barite,** occurs in nature in rhombic prisms and amorphous. Sp. gr. 4.6. It is obtained as a white amorphous powder, insoluble in acids and water, by the action of sulphuric acid upon barium salts. It is used as an adulterant of white paint, Paris green, and a variety of other commercial products.

Barium Carbonate ($BaCO_3$) also occurs native as **witherite.** It precipitates from solutions of barium salts, as a white amorphous powder, when they are treated with soluble carbonates.

Physiological Effect of Barium Salts.—All the soluble compounds of barium, as well as those that are converted into soluble compounds in the stomach, are poisonous. Whenever a poisonous dose has been taken, the patient should take some soluble sulphate (as Epsom or Glauber's salt), followed by an emetic. The symptoms of poisoning are pain in stomach, prostration, dilated pupils, loss of voice, sight, or hearing, excessive micturition, and other very prominent nervous symptoms. Post-mortem, inflammation, and, in most cases, great friability of the stomach, and, invariably, inflammation of the rectum are found.

GROUP III.—METALS OF THE MAGNESIUM GROUP.

Magnesium, **Mg** = 24.
Zinc, **Zn** = 65.3.
Cadmium, **Cd** = 112.
Mercury, **Hg** = 200.

MAGNESIUM.

Mg = 24.

Magnesium was formerly classed with the metals of the alkaline earths, but its sulphate is soluble and its chloride volatile, which, together with its properties in the free state, show it to be more closely related to zinc.

Occurrence.—It is found abundantly in nature. Some of the most common minerals containing it are **magnesite,** $Mg. CO_3$; **kieserite,** $Mg. SO_4, H_2O$, **carnallite,** $KCl.Mg Cl_2 .6 H_2O$, and **dolomitd,** $MgCaCO_3$.

Dolomite, an amorphous mixture of calcium and magnesium carbonates, forms the so-called magnesian limestone. **Asbestos,**

serpentine, meerschaum, talc or **soapstone,** and **hornblende** are native silicates. Nearly all natural waters contain some of the soluble salts of magnesium, which impart hardness to them.

Preparation.—It may be obtained either by electrolysis of the chloride, or by heating the same compound with sodium. It was formerly prepared by fusing the double chloride of sodium and magnesium with metallic sodium.

$$MgCl_2.NaCl + 2Na = 3NaCl + Mg.$$

It is now generally prepared by the electrolysis of the fused chloride, or the native carnallite.

The electrolysis is conducted in a steel vessel, which is made the negative pole, and the positive pole is made of gas retort carbon. The current is supplied by a powerful dynamo, and a current of hydrogen is led into the chamber during the reduction to prevent oxidation of the metal. It is then purified by distillation in an atmosphere of hydrogen.

Properties.—Magnesium is a brilliant white, very tenacious and ductile, metal of a sp. gr. of 1.75. It fuses at a dull red heat, and at a bright red heat it distils. It oxidizes but slightly in the air, at ordinary temperatures, but when heated, it burns with an intensely brilliant bluish white light, owing to the incandescence of the magnesium oxide formed in the burning. The flame of burning magnesium is rich in chemically active or actinic rays; hence it is much employed for photographing in dark caves and subterraneous chambers. It combines directly with chlorine, sulphur, phosphorus, arsenic and nitrogen. It is soluble in dilute acids, but not in alkalies. It is slowly oxidized by boiling water.

Magnesium Chloride ($MgCl_2$) exists in small quantities in many mineral springs and in sea-water, to which it imparts a bitter taste. It may be obtained by dissolving the carbonate or oxide in hydrochloric acid. It forms deliquescent crystals, isomorphous with calcium chloride, containing 6 molecules of H_2O. The anhydrous chloride is one of the most deliquescent substances known.

Magnesium Oxide—Calcined Magnesia—Magnesia (U. S., Br.), (MgO)—is formed by the combustion of the metal, or by the ignition of the carbonate, hydroxide, or nitrate. It is a very light, white powder, without odor or taste, and has a feeble alkaline reaction. It is soluble in diluted acids.

A compact variety, prepared by heating the nitrate or chloride to bright redness, and no higher, exhibits remarkable hydraulic properties. If moistened with water to a paste, it quickly hardens to a compact white solid, of great hardness and durability. If it be mixed with an equal part of marble dust or chalk, and moistened, it may be moulded into any desired shape, and on being placed in water, it "sets" into an extremely hard mass. It has been used as a filling for decayed teeth.

Magnesia Ponderosa (U. S. P.), or heavy magnesia, does not differ in chemical composition from the light variety, but it differs merely in its physical condition.

Magnesium Hydroxide—Hydrated Magnesia, $Mg(HO)_2$—is formed from any soluble magnesium salt by precipitating with sodium or potassium hydroxide. It is almost insoluble in water and alkalies, but soluble in ammonium salts with the formation of double salts. A mixture holding it in suspension in water, known as **milk of magnesia**, is used in medicine as a laxative and as an antidote for acid poisons.

Magnesium Sulphate—Epsom Salt—Magnesii Sulphas (U. S. P.)—**Magnesiæ Sulphas** (Br.), $(MgSO_4).7H_2O$—is found in solution in sea waters and in many mineral springs, especially those belonging to the class of **bitter waters.**

It is prepared by the action of sulphuric acid upon magnesium carbonate. At ordinary temperatures it crystallizes with 7 molecules of H_2O, in four-sided rhombic prisms, which are very readily soluble in water. When heated, it fuses and parts with its water of crystallization up to 132° C. (269.6° F.), when it has lost all but one molecule; this it finally parts with when heated to 200° C. (392° F.). **One** molecule of water, therefore, is more closely combined than the rest. That is known as the **Water of Constitution.**

Magnesium Phosphates.—These resemble the calcium phosphates, which they generally accompany in the animal body, though usually existing in smaller quantities. Magnesium also forms double phosphates, one of which, the **Ammonio-magnesium phosphate**, or **triple phosphate** ($MgNH_4PO_4.6H_2O$), is precipitated when an excess of an alkaline phosphate and of ammonia is added to a solution containing magnesium. When the urine becomes ammoniacal from the decomposition of urea, this salt is precipitated, as urine always contains alkaline phosphates and magnesium salts. Being practically insoluble, especially in the presence of excess of phosphates and of ammonia, it is usually deposited from the urine as a sediment, in the shape of modified right rhombic prisms, which, under the microscope, resemble the shape of a coffin lid. This sometimes takes place in the bladder, and if some body is present that will act as a nucleus, the so-called **fusible calculus** may form.

Magnesium Carbonate—Neutral Carbonate ($MgCO_3$)—occurs in nature as **magnesite,** and, combined with calcium carbonate, in **dolomite.** On adding an alkaline carbonate to an aqueous solution of a magnesium salt, magnesium carbonate is not produced, as most other carbonates would be under similar circumstances, but some carbon dioxide escapes, and a white precipitate falls, which is a mixture of magnesium carbonate and hydroxide, or **magnesia alba.**

Tetramagnesium Carbonate—Magnesia Alba—Magnesii Carbonas (U. S. P.), **Magnesiæ Carbonas** (Br.), $(4(MgCO_3).(MgH_2O_2 + 5H_2O)$—occurs in commerce in light white cubes, composed of an amorphous or partly crystalline powder. It is prepared by precipitating a solution of magnesium sulphate with one of sodium carbonate. A hot concentrated solution should be used, and the liquid boiled after precipitation. This compound varies in constitution according to the length of time that the boiling has continued and the presence or absence of excess of sodium carbonate. It is very slightly soluble in water, but quite soluble in solutions of ammonium chloride.

Magnesii Citras effervescens is a granular salt consisting of citrate of magnesium with an excess of citric acid, and some sodium bicarbonate. When dissolved in water it effervesces copiously, carbon dioxide being evolved. It has a mildly acidulous and refreshing taste.

ZINC.

$Zn = 65.1.$

Occurrence.—The native compounds of the heavy metals are termed **ores.** The most common zinc ores are **Smithsonite** ($ZnCO_3$.), **Calamine** (**Silicate,**) and **Sphalerite** or **Blende** (ZnS). These, like most ores, have a high specific gravity, and are usually found in veins in the older crystalline rocks.

Preparation.—To obtain the metal, one of its ores, usually the carbonate or sulphide, is converted into an oxide by roasting at a high temperature. This oxide is then mixed with carbon and ignited in cylindrical earthenware retorts, reducing the oxide thus:—

$$ZnO + C = Zn + CO.$$

The free zinc is then distilled off, and condensed in iron receivers, which are placed like caps over the opening of the retorts. The metal so obtained forms the **spelter** of commerce, and contains various impurities, such as iron, lead, arsenic, sulphur, and cadmium.

Zinc is purified by subjecting it to a second distillation. This is generally conducted in a covered vertical retort, which is provided with a tube which passes through its bottom. The upper end of this tube reaches nearly to the top of the retort, and its lower extremity is just above a vessel of water. When the zinc is heated in this retort, it volatilizes, and passes down the tube, and is condensed in the water. This method is known as "distillation per decentum."

Properties.—It is a bluish-white metal, roughly crystalline or granular; its specific gravity is 6.862, if cast; 7.215, if rolled. It is brittle at ordinary temperatures and can be pulverized; at 100° C. (212° F.) to 150° C. (302° F.), it is malleable and ductile, and may be rolled into thin sheets. At 200° C. (392° F.) it again becomes brittle. It fuses at 412° C. (773° F.), and distils at 1040° C. (1904° F.). In moist air it becomes coated with a thin layer of basic carbonate. When heated in the air, it burns with a very intense bluish-white light, with the formation of the oxide. It dissolves readily in diluted acids with the evolution of hydrogen. Concentrated sulphuric acid does not dissolve zinc. It is soluble in sodium, potassium, and ammonium hydroxides. On account of the slight action of the air upon it, zinc meets with extensive application in architecture, and for galvanizing or coating iron. **Zincum** is official in the U. S. P. in the form of thin sheets, or granular pieces, or moulded into pencils, or in powder form. Granulated Zinc is made by melting the metal and pouring it into water.

Zinc Chloride—Butter of Zinc—Zinci Chloridum (U. S. P., Br.), ($ZnCl_2$)—is obtained by heating zinc in a stream of chlorine, by dissolving zinc in hydrochloric acid, and by the distillation of zinc sulphate with calcium chloride. It forms a soft white mass, which is very deliquescent, is fusible and volatile. It is extremely soluble in water, and freely so in alcohol. The solution has a burning metallic taste, destroying animal and vegetable tissues, and possessing strong dehydrating properties. It forms a series of double salts. The double chloride of zinc and ammonium is sometimes used in soldering, to cleanse the surface of metals to be soldered.

Zinci Bromidum ($ZnBr_2$) (U. S. P.) may be made by dissolving zinc in hydrobromic acid, or by the direct combination of zinc and bromide.

$$2Zn + 4HBr = 2ZnBr_2 + H_4.$$

It is a white granular powder, having no odor, but a sharp metallic taste, very soluble in water and in alcohol, and very deliquescent.

Zinci Iodidum (ZnI_2) (U. S. P.) may be made by digesting small fragments of zinc in water containing some iodine, or by dissolving zinc carbonate or oxid in hydriodic acid.

$$ZnO + 2HI = ZnI_2 + H_2O.$$

The solution is filtered through powdered glass and evaporated. It is a deliquescent, granular white odorless powder. It is soluble in water and in alcohol

Zinci Phosphidum (Zn_3P_2), (U. S. P.) is made by passing the vapor of phosphorus in a current of dry hydrogen gas over fused zinc. It is a dark gray colored, gritty powder, or fragments. It has a metallic lustre and a faint odor of phosphorus. It is insoluble in water or alcohol.

Zinc Oxide—Zinci Oxidum (U. S. P., Br.), (ZnO)—may be prepared by igniting the precipitated basic carbonate, or by burning the metal in a current of air. When obtained in the former way, it forms a soft, white, tasteless and odorless powder. When produced by burning the metal, it occurs as a white, voluminous, flocculent mass, formerly called **flores zinci** or **lana philosophica.** It neither fuses, volatilizes, nor decomposes by heat, and is insoluble in neutral solvents. It is used in the arts as a white pigment, and is not darkened by hydrogen sulphide, as is white lead.

Zinc Hydroxide ($Zn(OH)_2$) is formed as a white amorphous powder, by precipitating an aqueous solution of a zinc salt by alkaline hydroxides. It is soluble in an excess of the alkaline hydroxides and in solutions of ammonium salts. When heated, it decomposes into zinc oxide and water.

Zinc Sulphate—White Vitriol—Zinci Sulphas (U. S. P., Br.), ($ZnSO_4.7H_2O$)—is formed by dissolving zinc, or its oxide, sulphide, or carbonate, in sulphuric acid.

$$2Zn + 2H_2SO_4 = 2ZnSO_4 + 2H_2.$$

$$ZnO + H_2SO_4 = ZnSO_4 + H_2O.$$

$$ZnCO_3 + H_2SO_4 = ZnSO_4 + CO_2 + H_2O.$$

At temperatures below 30° C. (86° F.), it crystallizes with 7 Aq; at 30° C. (86° F.), with 6 Aq.; between 40° C. (104° F.) and 50° C. (122° F.), with 5 Aq. The most common salt is that with 7 Aq., which occurs in rhombic crystals resembling magnesium sulphate, and is freely soluble in water. It is used in medicine as an emetic and astringent.

Zinci Acetas (U. S. P.) ($Zn(C_2H_3O_2)_2$) $.2H_2O$, is made by dissolving the carbonate or oxide of zinc in diluted acetic acid, evaporating, and crystallizing.

$$ZnO + 2HC_2H_3O_2 = Zn(C_2H_3O_2)_2 + H_2O.$$

It is in soft, white tablets or scales, having a pearly lustre, a faint odor of acetic acid, and a sharp metallic taste. It is soluble in 2.7 parts of water at 15° C. (59° F.), in 1.5 parts of boiling water, and in 36 parts of alcohol.

Zinci Valerianas ($Zn(C_5H_9O_2)_2 . 2H_2O$) (U. S. P.) is in white, pearly scales, having a strong odor of valerianic acid, and a peculiar, sweet, styptic, metallic taste. Exposed to the air, it is decomposed, giving off valerianic acid. It is made by mixing hot solutions of sodium valerianate and zinc sulphate, and allowing the zinc valerianate to crystallize out.

Zinci Carbonas Precipitatus.—This salt is made by mixing a boiling solution of sodium carbonate with a boiling solution of zinc sulphate. Mutual decomposition takes place and a hydrated, basic zinc carbonate is precipitated.

$$5ZnSO_4 + 5Na_2CO_3 + 3H_2O = \underbrace{(ZnCO_3)_2 . (Zn(OH)_2)_3}_{\text{Precipitated Zinc Carbonate.}} + 5Na_2SO_4 + 3CO_2.$$

The precipitate is washed with hot water and dried.

It is a white, impalpable powder, odorless and tasteless, insoluble in water or alcohol, and of variable chemical composition. The composition of the precipitate varies according to the temperature used.

Toxicology.—The compounds of zinc that are soluble in the digestive fluids are all irritant poisons. Solutions of the chloride (used by tinsmiths, in embalming, and as a disinfectant in Burnett's fluid) are also very corrosive. The antidotes are alkaline carbonates, soap, albumin, and mucilage. Solutions containing sodium chloride or organic acids act as solvents upon metallic zinc; consequently, symptoms of poisoning, more or less marked, are apt to follow the eating of acid fruits that have been kept in vessels of galvanized iron. On this account, specimens intended for analysis, in case of supposed poisoning, should never be placed in jars closed by zinc caps.

Tests.—With **alkaline hydroxides and carbonates,** solutions of zinc give a white precipitate, soluble in an excess of the reagent; with **ammonium sulphydrate** or **sulphydric**

acid, in neutral or alkaline solutions, a white sulphide; with **potassium ferrocyanide**, a yellowish-white precipitate, insoluble in diluted hydrochloric acid.

CADMIUM.

Cd = 112.

Occurrence, Preparation, Properties, etc.—It is a comparatively rare metal, often accompanying zinc in its ores. Being more volatile than its associate, it accumulates during the first stages of the process of distilling zinc from its ores. It is a soft, white, tenacious metal, of specific gravity 8.6. It alters but little in the air at ordinary temperatures. Heated, it burns, with the formation of the oxides, as a brown smoke. It dissolves with difficulty in sulphuric and hydrochloric acids, but readily in nitric acid.

Cadmium Compounds.—These are not very numerous or important. As the element is bivalent, they all have the general formula, CdR_2. The principal ones are: cadmium hydroxide ($Cd(OH)_2$), cadmium oxide (CdO), cadmium chloride ($CdCl_2$), cadmium iodide (CdI_2), cadmium sulphate ($CdSO_4$), and cadmium sulphide (CdS). The latter is found native in the mineral **greenockite**.

Cadmium iodide and bromide are used in photography. The latter itself enters into the composition of several alloys, which are used for filling teeth, such alloys having a low fusing point.

MERCURY (Quicksilver).

Hg = 200.

Occurrence.—Mercury occurs in nature principally as **cinnabar**, HgS, or, rarely, in the form of small particles of metal scattered through rocks. It is found in Spain, Peru, China, Japan, California, and Mexico.

Preparation.—The native sulphide, or cinnabar, is roasted in reverberatory furnaces, thus burning out the sulphur, and distilling off the mercury, which is then condensed. Or, it is sometimes simply heated with iron, which combines with the sulphur and sets free the mercury, which distils over. Commercial mercury usually contains small quantities of other metals, owing to its great tendency to amalgamate with them. To remove these it is re-distilled, or treated with very dilute acids by pouring it in a thin stream into them. When pure, mercury pours from a glass surface without leaving a streak; *i. e.*, the single droplets retain their globular form, and do not form a tail or adhere to the glass.

Properties.—Mercury is the only liquid metal at ordinary temperatures. Its specific gravity is 13.596. At —40° C. it solidifies and crystallizes in octahedra. It is somewhat volatile at ordidary temperatures, and boils at 360° C. (680° F). Its vapor has a density of 100; specific gravity 6.97 (Air = 1). Its molecular weight, therefore, is 200; and as its atomic weight is also 200, its molecule, like that of cadmium, is composed of **one** atom. If pure, and at ordinary temperatures, it is not altered in the air, but at a temperature near the boiling point it becomes coated with a thin film of mercuric oxide. Hot sulphuric acid converts it into mercuric sulphate, with the evolution of sulphur dioxide. It dissolves readily in dilute nitric, but not in hydrochloric acid.

Mercury alloys with and dissolves all metals except iron, to form **amalgams.** Tin amalgam is used for coating mirrors

Mercury forms two series of compounds, the mercurous and mercuric. The mercurous are less stable, and contain a larger percentage of the metal. They are less soluble, and consequently less poisonous.

Mercuric.	*Mercurous.*	*Mercuric.*	*Mercurous.*
HgO	Hg_2O	HgI_2	Hg_2I_2
HgS	Hg_2S	$Hg\ NO_3)_2$	$Hg_2(NO_3)_2$
$HgCl_2$	Hg_2Cl_2	$HgSO_4$	Hg_2SO_4

Mercurous Compounds. Mercurous Chloride—Protochloride—Mild Chloride—Calomel—Hydrargyri Chloridum Mite (U. S. P.)—**Hydrargyri Subchloridum** (Br.), ($HgCl$ or Hg_2Cl_2)—is usually prepared by the mutual decomposition of sodium chloride, mercuric sulphate, and mercury. After mixing thoroughly in a mortar, the mixture is heated, when the calomel sublimes.

$$HgSO_4 + 2NaCl + Hg = Na_2\ SO_4 + Hg_2Cl_2.$$

By this method mercuric chloride is also formed in varying quantities, and should be removed by washing the product with boiling distilled water, until the washings no longer form a precipitate with ammonium hydroxide.

Mercuric chloride may be detected in calomel by its forming a black stain upon a bright iron surface dipped in a mixture of calomel and alcohol; or, by the production of a black stain by hydrogen sulphide in water that has been filtered through calomel so contaminated. Calomel crystallizes when sublimed, in radiating quadratic prisms; but if precipitated from solutions of mercurous salts by hydrochloric acid, it forms a heavy, white, amorphous powder. Heated to about 500° C. (932° F.), it sublimes without fusing, is insoluble in cold water and alcohol, and dissolves in boiling water to the extent of 1 part in 12,000. If boiled for a long time with water, it partly decomposes, mercury being deposited, and mercuric chloride passing into solution. Strong acids convert it into mercuric salts and free mercury. With ammonium hydroxide it blackens, with the formation of **mercurous amidogen-chloride.**

$$Hg_2Cl_2 + 2NH_4OH = NH_4Cl + NH_2Hg_2Cl + 2H_2O.$$

Hydrochloric acid and alkaline chlorides convert it into mercuric chloride; this may occur in the stomachs of persons who use large quantities of salted food, as on board ship. Alkaline iodides convert it into mercurous iodide, which is then decomposed by an excess of the alkaline iodides into mercuric iodide and mercury.

Mercurous Iodide—Protiodide, or Yellow Iodide—Hydrargyri Iodidum Viride (U. S. P., Br.), (HgI or Hg_2I_2) —is prepared by triturating 200 parts of mercury with 127 parts of iodine and a little alcohol, until a green paste is formed. It may also be prepared by precipitation from a solution of $Hg_2(NO_3)_2$ with KI.

$$Hg_2(NO_3)_2 + 2KI = Hg_2I_2 + 2KNO_3.$$

It is a greenish-yellow, amorphous powder, insoluble in water and alcohol. It turns brown, and volatilizes when heated. Light decomposes it into mercuric iodide and mercury. When moderately heated, it becomes red, but upon cooling, it resumes again its yellow color. But when strongly heated it is decomposed into the red mercuric iodide and mercury.

Mercurous Oxide—Protoxide, or Black Oxide (Hg_2O) —is formed by the action of sodium hydroxide upon mercurous salts.

$$Hg_2(NO_3)_2 + 2NaOH = Hg_2O + 2NaNO_3 + H_2O.$$

It is a brownish-black, tasteless powder, which sunlight decomposes into mercuric oxide and mercury. Mineral acids convert it into the corresponding mercurous salts. It exists in the **lotio**

hydrargyri nigri (Br.), or **black wash.** This is made by adding calomel to lime water.

$$Hg_2Cl_2 + Ca(OH)_2 = Hg_2O + CaCl_2 + H_2O.$$

Mercurous Nitrate ($HgNO_3$ or $Hg_2(NO_3)_2$) is formed by digesting an excess of mercury with a somewhat diluted nitric acid, until short prismatic crystals separate.

$$6Hg + 8HNO_3 = 3Hg_2(NO_3)_2 + 4H_2O + N_2O_2.$$

The crystals effloresce in the air. Water decomposes this salt into the acid salt which goes into solution, and **basic mercuric nitrate** $\left(\mathrm{Hg}\begin{matrix}\diagup \mathrm{OH}\\ \diagdown \mathrm{NO_3}\end{matrix}\right)$ which separates as a yellow powder. Water acidulated with nitric acid dissolves it, but it soon oxidizes and becomes mercuric nitrate. By adding metallic mercury to the solution, this oxidation is prevented to a great degree, or, after oxidation, reduces it again to the **mercurous** state.

$$Hg(NO_3)_2 + Hg = Hg_2(NO_3)_2.$$

Mercurous Sulphate (Hg_2SO_4) is formed by gently warming an excess of mercury with sulphuric acid. It separates as a yellow crystalline precipitate when sulphuric acid is added to a mercurous nitrate solution.

Mercuric Compounds.—In these, mercury is bivalent; they are represented by the formula HgR_2. The mercuric compounds are always formed when mercury is dissolved in an excess of acid; when the opposite is the case, the **ous** compounds are formed. The addition of metallic mercury to the mercuric compounds converts them into mercurous compounds, while oxidizing agents produce the opposite effect.

Mercuric Chloride—Bichloride—Corrosive Sublimate—Hydrargyri Chloridum Corrosivum (U. S. P.), **Hydrargyri Perchloridum** (Br.), ($HgCl_2$)—may be produced by dissolving mercuric oxide in hydrochloric acid.

On a large scale, it is prepared by subliming a dried mixture of mercuric sulphate and sodium chloride.

$$HgSO_4 + 2NaCl = HgCl_2 + Na_2SO_4.$$

It crystallizes by sublimation in rectangular octahedra; from solution, in fine, right, rhombic, needle-like prisms. At ordinary temperatures, it dissolves in 16 parts of water, and at 100° C. (212° F.), in 3 parts; it is still more soluble in alcohol. It dissolves freely in hot hydrochloric acid, which solution gelatinizes on cooling. Its specific gravity is 5 4. In aqueous solution, it tends to reduce to calomel. Sodium or ammonium chloride prevents this change. Zinc, cadmium, nickel, iron, lead, copper, and bismuth, remove most of its chlorine, reducing it either to metallic mercury or calomel. Sulphuric, nitric, and hydrochloric acids all dissolve it without decomposition. When its aqueous solution is treated with a hydroxide of an alkali, or alkaline earth, a yellow precipitate of mercuric oxide (HgO) is formed.

This is formed in **lotio flava,** or **yellow wash,** which is made by mixing 30 grains of mercuric chloride with a pint of lime-water. Mercuric chloride prevents putrefaction. It is an excellent antiseptic, much used in surgical operations. Its solution is used for preserving and hardening anatomical specimens. With albumin, it forms a white precipitate, insoluble in water, but soluble in excess of albumin solution, or in solutions of alkaline chlorides.

Mercur-Ammonium Chloride—White Precipitate—Ammoniated Mercury — Hydrargyrum Ammoniatum (U. S., Br.), (NH_2HgCl)—is thrown down as a heavy white precipitate, by adding a slight excess of ammonium hydroxide to a solution of mercuric chloride.

$$HgCl_2 + 2NH_4OH = NH_2HgCl + NH_4Cl + 2H_2O.$$

This salt is sometimes called "amido-chloride of mercury," and may be looked upon as a compound of mercury, chlorine, and amidogen (NH_2).

Ammoniated mercury occurs in white pulverulent pieces, or in powder. It has no odor, but an earthy and metallic taste. It is used in the official **Unguentum hydrargyri ammoniati.** It is insoluble in alcohol, ether, and cold water. Hot water decomposes it, with the separation of a heavy yellow powder. It sublimes without fusing.

Mercuric Iodide — Biniodide, or Red Iodide — Hydrargyri Iodidum Rubrum (U. S., Br.), (HgI_2)—is formed when solutions of mercuric chloride and potassium iodide are mixed.

$$HgCl_2 + 2KI = HgI_2 + 2KCl.$$

A double decomposition takes place, and the mercuric iodide separates as a yellow precipitate, which immediately turns bright red. It is sparingly soluble in water, but freely soluble in solutions of KI and alcohol, forming clear solutions. It also dissolves in many diluted acids, and in solutions of ammonium salts, alkaline chlorides, and mercuric salts. From its alcoholic solution, it crystallizes in bright red, rhombohedral crystals. When heated, it becomes yellow, fuses, and sublimes in yellow, shining, rhombic needles. These again become red upon touching them with some solid, and are changed into a mass of octahedra. Mercuric iodide is, therefore, **dimorphous.** HgI_2 enters into Donovan's Solution.

Mercuric Oxide—Red Oxide, or **Binoxide—Hydrargyri Oxidum Flavum** (U. S., Br.)—**Hydrargyri Oxidum Rubrum** (U. S. Br.), (HgO)—is obtained by igniting mercurous or mercuric nitrate as long as fumes are given off,

$$2Hg(NO_3)_2 = 2HgO + 2N_2O_4 + O_2;$$

or, by adding sodium hydroxide to a solution of a mercuric salt.

$$HgCl_2 + 2KOH = HgO + 2KCl + H_2O.$$

The product obtained by the first method is red and crystalline, of sp. gr. 11.2; that obtained by precipitation is yellow and amorphous, furnishing **Hydrarg. oxid. flavum** (U. S. P.). The latter is the more active form. Both modifications turn black when exposed to the light and air. At 400° C. (752° F.) they break up into mercury and oxygen. Mercuric oxide is very sparingly soluble in water. It is the chief ingredient of the **Lotio hydrargyri flava** (Br.), or **yellow wash.**

Mercuric Nitrate ($Hg(NO_3)_2$) may be obtained by dissolving mercury or mercuric oxide in hot nitric acid.

$$HgO + 2HNO_3 = Hg(NO_3)_2 + H_2O.$$

This should be carefully conducted, as it is inclined to form basic salts. It dissolves in water, and exists in the **Liq. hydrargyri nitratis** (U. S.), or **Liq. hydrargyri nitratis acidus** (Br.). It is used in the volumetric estimation of urea by Liebig's method. The standard solution used for this purpose contains 71.48 grms of metallic mercury to the liter, and 1 c.c. precipitates 10 mgrms. of urea.

Mercuric Sulphate ($HgSO_4$) is prepared by warming mercury or its oxide with an excess of sulphuric acid.

$$Hg + 2H_2SO_4 = HgSO_4 + SO_2 + 2H_2O.$$

It is a white, crystalline salt, used as the exciting agent in some forms of galvanic batteries. With an excess of water, it decomposes into sulphuric acid and the yellow insoluble basic salt, **Turpeth mineral,** $HgSO_4.2HgO$. This is official in the U. S P. under the names **Hydrargyri subsulphas flavus,** yellow mercuric bisulphate.

Mercuric Sulphide—Red Sulphide—Cinnabar—Vermilion—Hydrargyri Sulphuretum Rubrum (U. S. P., 1880) (HgS)—occurs native in radiating or amorphous masses. It may be prepared by rubbing sulphur and mercury together, or by the precipitation of a mercuric salt by hydrogen sulphide, as a black amorphous mass, which is the **Æthiops mineralis** of the older pharmacists.

$$HgCl_2 + H_2S = HgS + 2HCl.$$

This may be converted into the red sulphide by subliming it. **Hydrargyri cyanidum** $Hg(Cn)_2$ is official.

Physiological Action of Mercury.—If introduced into the animal economy, metallic mercury is not poisonous. By contact with alkaline chlorides, however, it is converted into mercuric chloride; the more finely divided the particles of mercury are, the more readily does this take place.

Mercuric chloride has a decidedly toxic action, both locally and constitutionally. Its local irritant action is due to its tendency to unite with albuminoid bodies. The constitutional symptoms are somewhat similar to those produced by arsenic, but appear sooner. The vomit frequently contains blood, and there is an intense burning, metallic taste in the mouth. The symptoms that are referable to the gastro intestinal mucous membrane are more intense. The size of the minimum fatal dose of the corrosive chloride is about three grains; of white precipitate, thirty to forty grains; and of Turpeth mineral, about forty grains. Children tolerate mercury much better than adults.

The treatment in acute poisoning should consist in the administration of milk or white of egg, and the induction of prompt emesis. Absorbed mercury probably exists in the blood as an albuminate, and is eliminated by the fæces, urine, and saliva; chiefly by the former. Chronic mercurial poisoning, known as **mercurial tremors, shaking palsy,** etc , is met with in those who work in mercury compounds. The symptoms usually begin with debility, nausea, vomiting, colicky pains, and a constant metallic taste in the mouth. Sooner or later salivation will become a prominent symptom; the tongue and gums becoming swollen, red and ulcerated, and the breath emitting a peculiar fetid odor. Salivation may, however, be produced by bromine, antimony, lead, prussic acid, etc.

Chronic and even acute poisoning may occur from the free external use of mercurial salts. **Post-Mortem** the mucous membrane of the stomach, in acute poisoning with $HgCl_2$, is usually found of a grayish color, as also that of parts of the mouth and œsophagus. The surface of the membrane is sometimes covered with a slate colored deposit of finely divided mercury.

Tests.—One of the simplest tests for mercury in solution is a piece of bright copper, which, in the presence of a small quantity of free hydrochloric acid, becomes coated with a silver white layer of copper amalgam. All salts of mercury are volatile. When heated in a tube with sodium carbonate, globules of metallic mercury distil off from all its salts. Mercury salts give a black precipitate with H_2S, which is insoluble in nitric acid, but soluble in aqua regia.

GROUP IV.

Boron,	B = 11.	Indium,	In = 113.7.
Aluminum,	Al = 27.	Lanthanum,	La = 138.2.
Scandium,	Sc = 44.	Erbium,	E = 166.
Gallium,	Ga = 69.	Ytterbium,	Yb = 173.
Yttrium,	Y = 89.1.	Thallium,	Th = 204.18.

Of the above elements but the first two are of sufficient interest to be described here.

BORON.

B = 11.

Occurrence and Preparation.—An unimportant element, never occurring native, but as borates and boric acid. Borates of calcium, magnesium, and sodium (borax) occur native; the last, the most important, is found in India and California. The element may be prepared in two allotropic states; the first, as a greenish-brown powder, by fusing its oxide with sodium or potassium; the second, as a crystalline transparent solid, by fusing the oxide, chloride or fluoride, with aluminum, varying in color from colorless to a garnet red. Boron combines directly with nitrogen at elevated temperatures.

Boric Anhydride and Acids.—B_2O_3 is a transparent, glass-like mass, obtained by heating boric acid to redness. It is used in blowpipe analysis.

Boric or **Boracic Acid** (H_3BO_3) exists native in lagoons, in the vicinity of volcanoes, and in Tuscany. By evaporation and crystallization the acid is obtained. **Borate of sodium,** or **borax,** occurs in California and India, and from it the pure acid is prepared by precipitating it with HCl from a hot solution.

$$Na_2B_4O_7.10H_2O + 2HCl = 2NaCl + 4H_3BO_3 + 5H_2O.$$

The acid separates in white, shining scales. It is soluble in 25 parts of H_2O at 14° C. (57.2° F.), and in 3 parts of boiling H_2O. The solution has a faint acid reaction. The acid is soluble in 15 parts of alcohol, and is also soluble in glycerin, to the flame of both of which it imparts a distinct green color; this, and the action on turmeric paper, are used as tests. If a strip of turmeric paper be dipped in a solution containing H_3BO_3, it turns reddish-brown on drying.

When boiled with glycerin, an ether is formed, known as **boroglycerid,** which is soluble in water, has a neutral reaction, is tasteless, and is used as a preservative for foods. Its use, as well as that of boric acid, is attended, in considerable doses, with an increased excretion of urea, irritation of the kidneys, and should be used with some caution. Owing to its antiseptic action it is used in surgical dressings.

Glyceritum boroglycerini (U. S. P.) is made by dissolving 31 per cent. of boric acid in glycerin.

When heated, H_3BO_3 loses one molecule of water at 100° C. (212° F.), and forms **metaboric** acid (HBO_2); on further heating it forms **tetraboric** acid ($H_2B_4O_7$), and at a higher temperature **boric anhydride.**

ALUMINUM (Aluminium).

$Al = 27.$

This metal is found very widely distributed. It exists as oxide in **ruby, sapphire,** and **corundum,** and, less pure, as **emery.** Most commonly it occurs as the silicate (clay, kaolin), and with other silicates, as **feldspar** and **mica,** and in most crystalline rocks. Emerald is a silicate of aluminum and glucinum. Garnet and topaz are also silicates of aluminum.

Cryolite is a double fluoride of aluminum and sodium.

Preparation and Properties.—Aluminum may be obtained in the metallic condition by igniting the chloride, or the double fluoride of sodium and aluminum, with sodium.

$$2Na_3AlF_6 + 3Na_2 = Al_2 + 12NaF.$$

It is now generally manufactured by the electrolysis of a mixture of cryolite (Na_3AlF_6) and aluminum oxide. The mixture fuses and then decomposes, giving almost chemically pure aluminum. Since the introduction of this method of manufacture the cost of the metal has greatly decreased, and its use greatly increased.

It is a silver-white metal, very malleable and ductile, a good conductor of electricity; sp. gr. 2.56. At ordinary temperatures it is not affected by air or oxygen, but burns if heated in oxygen. It is insoluble in nitric acid, but soluble in boiling sulphuric and cold hydrochloric acids. It dissolves in alkaline hydroxides to form **aluminates**, with the liberation of hydrogen. It forms a hard and durable alloy with copper, known as **aluminum bronze.**

Aluminum Chloride (Al_2Cl_6) is obtained by the action of chlorine upon heated aluminum. It forms colorless hexagonal prisms, fusible, volatile, and very soluble in water and alcohol. It crystallizes from a hot concentrated solution with $12H_2O$.

Aluminum Oxide — Alumina (Al_2O_3)—is found crystallized in prisms, and colored by other admixtures in **ruby, sapphire,** and **corundum.** These minerals are all exceedingly hard, ranking next to the diamond in this respect. Alumina may be obtained artificially, by igniting the hydroxide as a light, white, insoluble, odorless, and tasteless powder. When prepared as above, acids attack it with great difficulty. It may be decomposed by fusing with caustic alkalies or acid potassium sulphate.

Aluminum Hydroxide ($Al_2(OH)_6$) is formed by precipitating a solution of an aluminum salt with ammonium hydroxide or carbonate. The **Alumini Hydras** (U. S. P.) is directed to be made by precipitating a solution of alum with sodium carbonate.

$$K_2Al_2(SO_4)_4 + 3Na_2CO_3 + 3H_2O = 3Na_2SO_4 + K_2SO_4 + Al_2(OH)_6 + 3CO_2.$$

When freshly precipitated it is insoluble in water, but soluble in solutions of the fixed alkalies. By prolonged drying, or after standing under water, it is rendered almost insoluble in acids, although it undergoes no change in composition or appearance.

Aluminum Sulphate — Alumini sulphas (U. S. P.) ($Al_2(SO_4)_3$)—is prepared artificially by the action of sulphuric acid upon kaolin or clay, and also by dissolving aluminum hydroxide in the same acid.

$$Al_2(OH)_6 + 3H_2SO_4 = Al_2(SO_4)_3 + 6H_2O.$$

It crystallizes in thin plates with $16H_2O$; soluble in water, and sparingly so in alcohol. When heated, it fuses and becomes anhydrous.

Alums.—These are double salts formed by the combination of aluminum sulphate with the alkaline sulphates. The salt originally known as **alum** is the double sulphate of aluminum and potassium ($K_2Al_2(SO_4)_4.24H_2O$). It is obtained from clays free from iron and from **aluminite,** a basic sulphate of aluminum. The potassium in this alum can be replaced by sodium, ammonium, rubidium, cæsium, and thallium. Potassium alum forms large, regular, transparent, octahedral crystals, soluble in water. Heated to about redness, it loses 45 per cent. of its weight of water, forming the product known as **burnt alum. Aluminum and ammonium sulphate,** or **ammonia alum,** $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$, is rapidly taking the place of the potassium alum, from which it differs in being more soluble in water between 20° C. (68° F.) and 90° C. (104° F.), and less soluble in water colder or warmer than this. At about the temperature at which potash alum loses its water, ammonia alum decomposes and loses its ammonia. Ferric iron, manganese, and chromium, may replace the aluminum in alum, and form a series of alums known as **ferric alum,** $Fe_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$, **manganese alum,** $Mn_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$, and **chrome alum,** $Cr_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$.

METALS OF GROUP V.

Vanadium, **V** = 51.
Columbium, **Cb** = 94.
Neodymium, **Nd** = 140.5.
Praseodymium, **Pr** = 143.5.
Tantalum, **Ta** = 182.6.

They are all rare metals not used in medicine.

METALS OF GROUP VI.

Chromium, $Cr = 52.1$.
Molybdenum, $Mo = 96$.
Wolfram (Tungsten), $W = 184.9$.
Uranium, $U = 239.6$.

Of these chromium and molybdenum will be noticed at length.

CHROMIUM.

$Cr = 52.1$.

Occurrence, Preparation, and Properties.—This metal most commonly occurs in chromite, or chrome iron ore, a ferroso-chromic oxide; also, rarely, as lead chromate. It may be isolated with difficulty from its oxide by reducing it with charcoal; or from the chloride by reducing with zinc. It is a hard, glistening, steel-gray metal, magnetic at low temperatures; sp. gr. 6.8. It oxidizes only at a red heat, and is soluble in hydrochloric acid and strong alkalies.

Chlorides.—Two chlorides are known: **Chromous Chloride** ($CrCl_2$), a white, crystalline solid, dissolving in water to form a blue solution; and **chromic chloride** (Cr_2Cl_6), occurring in large red crystals, insoluble in water, unless a trace of the chromous chloride be present, when it dissolves readily. If it be subjected to a prolonged boiling with water, it finally dissolves, forming a green solution containing a hydroxide. An oxychloride is also known.

Chromic Anhydride—Chromic Trioxide (CrO_3).—This is sometimes improperly called chromic acid. It is prepared by adding one and one-half parts of strong sulphuric acid to one part of concentrated solution of potassium dichromate. When the solution cools, splendid saffron-colored needles of the trioxide crystallize out, which may be dried on a porous tile. It is a powerful oxidant, igniting alcohol if the latter be poured upon it. It is used in medicine as a caustic, forming a superficial eschar.

Chromic Oxide — Chromium Sesquioxide — Green Oxide ($Cr_2{}^{VI}O_3$)—is obtained by calcining a mixture of starch and potassium dichromate. Thus prepared, it is a green powder, insoluble in water, acids, or alkalies, and fusible with difficulty. When fused with alkaline hydroxides or nitrates, it forms chromates of these metals.

This oxide may play either a positive or a negative rôle, depending upon the oxide with which it unites. For example, with the strongly negative sulphuric oxide, it forms chromium sulphate ($Cr_2(SO_4)_3$); while with calcium or magnesium oxide, calcium or magnesium chromates ($CaCrO_4$ or $MgCrO_4$) are obtained.

Chromous Hydroxide ($Cr(OH)_2$).—This compound is produced by precipitating chromous chloride with potassium hydroxide. It acts as a basic oxide, yielding chromous salts.

Chromic Acid (H_2CrO_4).—This cannot be isolated, but by solution of chromium trioxide in water, an acid liquid is obtained containing chromic acid. This acid decomposes on evaporation.

The best known of the salts of this acid are potassium chromate and dichromate (K_2CrO_4 and $K_2Cr_2O_7$). The last of these possesses the properties of the trioxide, but in a milder degree. It is sometimes used as an escharotic, but much more frequently as an oxidizing agent, when mixed with sulphuric acid. None of the other preparations of chromium are used in medicine. Internally, in large doses, it acts as an irritant poison.

Chromic Sulphate ($Cr_2(SO_4)_3$) is obtained by dissolving chromic oxide in sulphuric acid; upon slowly evaporating, it crystallizes with twelve molecules of water.

Chromium salts form two series, the one green and the other violet. The alkaline hydroxides throw down a bluish-green hydroxide from the green salts, and a violet from the violet.

Chromium sulphate exists as a violet crystalline solid, and as a green amorphous solid. With the alkaline sulphates, chromium sulphate forms double salts—the chromium alums. (See page 284.)

Potassium Chromate (K_2CrO_4) is obtained by adding a solution of potassium hydroxide to one of potassium dichromate.

$$K_2Cr_2O_7 + 2KOH = 2K_2CrO_4 + H_2O.$$

It forms large, yellow, rhombic crystals, isomorphous with potassium sulphate (K_2SO_4).

Potassium Dichromate ($K_2Cr_2O_7$), commercially known as the **red chromate of potash** and often called the acid potassium chromate, is obtained by igniting pulverized **chromite** (Cr_2O_3FeO) with potassium carbonate and nitrate, forming potassium chromate and ferric oxide. The potassium chromate is dissolved out with water, and nitric or acetic acid added to the solution, from which potassium dichromate crystallizes. It forms large, red prisms, soluble at ordinary temperatures in ten parts of water. When it is warmed with sulphuric acid, oxygen escapes, and chromic oxide and potassium chrome alum are produced.

This mixture is employed in laboratories for oxidizing purposes.

Barium chromate ($BaCrO_4$) and lead chromate ($PbCrO_4$) are used as yellow pigments; the former under the name of *yellow ultramarine* and the latter as *orange chrome*.

Toxicology.—The chromates, especially potassium dichromate, are irritant poisons. They are also liable to produce a form of chronic poisoning in workmen handling them, characterized by ulceration of the septum of the nose, and of the skin. The most prominent symptoms in acute poisoning are vomiting, epigastric pain, cramps, excessive thirst, and collapse. The treatment consists in the use of emetics, followed by magnesium carbonate in milk.

MOLYBDENUM.

Mo = 96.

This element is of little importance itself, but some of its compounds are used.

Molybdic Trioxide or Anhydride (MoO_3).—This oxide is obtained by roasting the native sulphide in an open vessel, at a red heat. The principal interest attached to it is its use in preparing **ammonium molybdate,** a reagent used to detect and estimate phosphoric acid.

The impure oxide obtained by roasting the mineral **molybdenite,** MoS_2, is dissolved in ammonium hydroxide, evaporated to dryness, re-dissolved in water, concentrated by evaporation, and allowed to crystallize. The soluble molybdates give a precipitate of MoO_3 on the addition of an acid; but it is soluble in **excess** of the acid. The molybdates give a white precipitate with the earthy metals. With phosphoric acid or the phosphates, a solution of ammonium molybdate containing an excess of nitric or hydrochloric acid first turns yellow, then deposits a yellow precipitate of molybdic trioxide, phosphoric acid, and ammonia, which is very soluble in ammonia water. This is a very delicate test for phosphoric acid. Pyrophosphates and metaphosphates do not give this reaction. **Arsenic acid** gives a similar precipitate.

TUNGSTEN (Wolfram).

W = 184.9.

Tungsten is not abundant. It occurs in the minerals **wolframite, schulite,** and **stolzite,** all of which are tungstates. Although generally regarded as a metal, it often plays the negative rôle to form tungstic acid and tungstates.

The element is a hard, brittle, difficultly fusible metal, permanent in the air, but burns to the oxide at a red heat. Of the compounds of tungsten, the sodium tungstate alone is of interest to the medical student.

Tungstic Acid (H_2WO_4) is a yellowish-white powder thrown down from boiling alkaline solutions of tungstic oxide by mineral acids. It forms with bases numerous salts, called tungstates, the most important of which is sodium tungstate ($Na_2WO_4.2H_2O$). This has recently attained considerable importance as a test for albumin in urine. A cold saturated solution of this salt, added to acid solutions of the proteids, coagulates them. This salt is used to render fabrics uninflammable.

GROUP VII.—METALS.

MANGANESE.

$Mn = 55.$

Occurrence.—Manganese is found widely distributed in nature. It occurs native in meteorites. Its most common ores are **pyrolusite** (MnO_2), **hausmannite** (Mn_3O_4), **braunite** (Mn_2O_3), **manganite** ($Mn_2O_3.H_2O$), and **rhodochrosite** ($MnCO_3$).

Preparation and Properties.—It is obtained in the metallic condition by heating its oxides with charcoal, similar to the smelting of iron. It is a grayish-white, brittle metal, very hard, and fusing with great difficulty; sp. gr. 7.2. Like the elements iron and chromium, it forms three series of compounds—the manganous (MnR_2), manganic (Mn_2R_6), and the salts of manganic acid, called **manganates.**

Manganous Compounds.—In these the metal is diatomic. These derivatives are the most stable, and constitute the most common of the manganese salts. They resemble the **ous** salts of iron and chromium, with which they are isomorphous. **Manganous Oxide** (MnO) results from the ignition of the carbonate with the exclusion of air. It is a greenish, amorphous powder, readily oxidizing in the air to Mn_3O_4. **Manganous hydroxide** ($Mn(OH)_2$) is formed by adding alkaline hydroxides to manganous solutions, as a reddish-white precipitate, which, exposed to the air, oxidizes to manganic hydroxide, and turns brown in color.

Manganous Salts.—Manganous Chloride ($MnCl_2$) occurs in rose-colored tabular crystals, which decompose on drying with the separation of hydrochloric acid. **Manganous Sulphate** ($MnSO_4$) crystallizes at ordinary temperatures with $4H_2O$. It is official. It occurs as colorless or pale rose-colored, prismatic crystals soluble in 0.8 part of water at 15° C (59° F.) and in 1 part of boiling water. With the alkaline sulphates it forms double salts; *e. g.*, $MnSO_4.K_2SO_4.5H_2O$. **Manganous Carbonate** ($MnCO_3$) is precipitated from maganous solutions by alkaline carbonates as a white powder, turning brown on exposure to the air. **Manganous Sulphide** (MnS) occurs in nature as alabandite, or manganese blende, and is precipitated from manganous solutions by alkaline sulphides as a flesh-colored hydrate ($MnS.H_2O$). In the air it also becomes brown.

Manganic Compounds.—These are isomorphous with and very closely resemble the ferric, chromic and aluminic compounds. They are not so stable, however, being easily reduced to the manganous state. In them manganese is a tetrad.

Manganese Dioxide — Manganic Peroxide — Black Oxide of Manganese (MnO_2)—occurs native as the mineral **pyrolusite,** the principal ore of manganese, in steel-gray or brownish imperfectly crystallized masses. It is official, and is used internally.

When greatly heated, it yields oxygen; at a red heat it yields more oxygen and forms manganous-manganic oxide.

$$3MnO_2 = Mn_3O_4 + O_2.$$

It gives off oxygen when heated with sulphuric acid, and forms manganous sulphate. With hydrochloric acid, it yields manganous chloride, water, and chlorine.

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

In cold hydrochloric acid, it dissolves, without setting chlorine free, as $MnCl_4$ is probably formed, which, upon heating, breaks up into $MnCl_2$ and Cl_2. From this it would appear that, in the dioxide, manganese is a tetrad.

Manganic Oxide (Mn_2O_3) is a black powder, produced by igniting the managnese oxides in a current of oxygen.

Manganous-manganic Oxide ($Mn_3O_4 = MnO.Mn_2O_3$).—This is formed by the ignition of all the oxides in the air; it is isomorphous with **Magnetite** (Fe_3O_4).

Manganic Hydroxide ($Mn_2(OH)_6$) is precipitated from manganic solutions by ammonium hydroxide as a flesh-colored precipitate, rapidly turning brown.

Manganic Sulphate ($Mn_2(SO_4)_3$) is produced by the action of sulphuric acid upon manganic hydroxide.

Manganates and Permanganates.—The derivatives of manganic acid ($H_2MnO_4 = MnO_2(OH)_2$) are analogous to those of ferric (H_2FeO_4), chromic (H_2CrO_4), and sulphuric acids (H_2SO_4). In these derivatives, manganese is a hexad. The manganates are of little permanency and little used.

Potassium Manganate (K_2MnO_4) is a rare substance, isomorphous with potassium sulphate or chromate, and is very readily converted into potassium permanganate.

Potassium Permanganate ($K_2Mn_2O_8$) or ($KMnO_4$) (U.S. P.) is precipitated from solutions of potassium manganate by acids, in dark-red rhombic prisms. It is made by boiling in water potassium hydroxide, potassium chlorate, and manganese dioxide, evaporating to dryness, and fusing.

$$6KOH + KClO_3 + 3MnO_2 = 3K_2MnO_4 + KCl + 3H_2O.$$

A greenish-colored mass—potassium manganate—is formed. This is dissolved in water, and is then easily decomposed by an acid or a large quantity of hot water.

$$3K_2MnO_4 + 3H_2O = K_2Mn_2O_8 + MnO_2 + 4KOH + H_2O.$$

Manganese dioxide is precipitated, and the permanganate remains in solution, from which it is obtained by crystallization. This salt has active oxidizing properties, and is very largely used for oxidizing and destroying organic substances. It also converts ferrous into ferric salts, and is used for the quantitative estimation of ferrous salts because of this property. It is also used to estimate organic matter in potable waters.

Condy's fluid is an aqueous solution of $K_2Mn_2O_8$.

GROUP VIII.

The members of the group are:—

Iron (Ferrum),	Fe = 56.	Rhodium,	Rh = 103.
Nickel,	Ni = 58.7.	Palladium,	Pd = 106.5.
Cobalt,	Co = 59.5.	Iridium,	Ir = 193.1.
Ruthenium,	Ru = 101.6.	Osmium,	Os = 190.8.
Platinum,	Pt = 195.		

Of these, iron, nickel, cobalt, osmium, and platinum are of sufficient interest to be given a place here.

IRON.

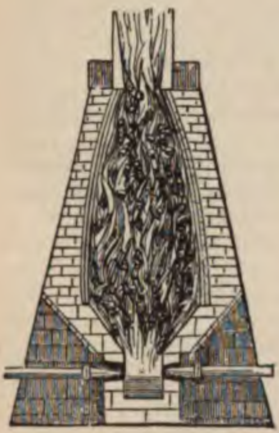
Fe = 56.

Occurrence.—This metal, which is of so great practical importance, is distributed very widely in nature. It occurs native upon the earth's surface only as meteorites.

The ores from which iron is obtained are numerous; the most important are: **magnetite** (Fe_3O_4), **hæmatite** (Fe_2O_3), **limonite** (ferric hydroxide), and **siderite** ($FeCO_3$). These are almost the only ores used for the manufacture of iron; the sulphur ores are not adapted to this purpose.

Preparation.—In some cases the ore is first roasted, to get rid of water, carbon dioxide, sulphur, etc. The next step consists in the extraction of the iron from the ores, in which it exists as an oxide. This is accomplished by reduction with carbon at a glowing heat. This reduction is effected in a **blast furnace** (Fig. 59), of which the interior has the shape of a double cone. It is about fifty or sixty feet high, by fifteen feet wide at its widest part, is built of the most infusible fire brick, and inclosed in solid masonry. It is filled at the top with alternate layers of coal, broken ore (either native or previously roasted), and fluxes in the form of limestone or silicates These fluxes facilitate the melting together of the reduced iron, and furnish a liquid slag. The air necessary for combustion, usually heated to a high temperature beforehand, is forced into the bottom of the furnace, through pipes, by blowers or fans. The metal is drawn off at the bottom. In the lower part of the furnace, carbon dioxide is produced from the oxygen of the air and the coal; higher up, carbon monoxide is produced, which acts upon the oxide of iron, reducing it to the metallic state. As the reduced iron sinks, it comes into contact with the coal, takes up a small quantity of carbon, and forms cast-iron, which, on further sinking, fuses, and is drawn

FIG. 59.



BLAST FURNACE.

off into moulds made in sand, to form **pig iron.** The earthy impurities of the ores, remaining in the furnace, unite with the fluxes, fuse in the intense heat, and are drawn off as **slag.** The pig iron is then subjected to the **puddling process,** by which it is more completely freed from carbon and slag, and **wrought iron** results. This process is usually carried on in reverberatory furnaces with a free supply of air, while the molten mass is being thoroughly stirred. The greater part of the carbon is in this way burned into carbon monoxide, and the silicon, sulphur and phosphorus oxidized. **Steel** was formerly prepared from wrought iron only, by **cementation,** or heating wrought-iron, packed in leather shavings or with charcoal. At present it is chiefly prepared directly from cast or pig iron by the method invented by Bessemer in 1850. This process consists in blowing air, under high pressure, into a mass of molten cast-iron, until the carbon has been burned out, when spiegeleisen, containing a known quantity of carbon, is added, to give the proper amount for steel. **Pure iron** is obtained by heating ferric oxide in a current of hydrogen; this is the **ferrum reductum** of the U. S. P.

$$Fe_2O_3 + 3H_2 = 3H_2O + Fe_2.$$

Properties. — Pure iron is soft, fuses at about 1600° C. (2912° F.), and has a specific gravity of 7.25 to 7.9. Iron is not affected by dry air at ordinary temperatures; in moist air, it covers itself with a thin layer of ferric hydroxide, known as **rust.** Heated strongly in the air, it becomes coated with a layer of ferrous-ferric oxide (Fe_3O_4), which is readily loosened, forming the blacksmith's scales. At a red heat, it decomposes water, with the formation of ferrous-ferric oxide, and the liberation of hydrogen.

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

It burns in oxygen with an intense, scintillating light. If brought into contact with a magnet, iron becomes magnetic. Tempered steel is the only form, however, that retains the magnetism.

Iron unites directly with chlorine, bromine, iodine, sulphur, and the members of the phosphorus group, except nitrogen. It dissolves readily in hydrochloric and sulphuric acids, with the evolution of hydrogen. In diluted nitric acid, it dissolves with the separation of nitric oxide. Concentrated nitric acid, however, renders it **passive,** when it is no longer attacked by the diluted acid, until the passive condition is destroyed by contact with silver, platinum, or copper, or by heating to 40° C. (104° F.).

Ferrous Compounds.—These are formed by dissolving iron in an acid, or by the reduction of ferric salts.

$$Fe_2Cl_6 + Zn = (FeCl_2)_2 + ZnCl_2.$$

They are usually of a green color in the hydrous state. Exposed to the air, they oxidize to ferric salts.

$$4FeO + O_2 = 2Fe_2O_3.$$

Ferrous Chloride ($FeCl_2$) is formed when iron is dissolved in hydrochloric acid. It crystallizes in green monoclinic prisms, containing four molecules of water. Exposed to the air, they deliquesce and oxidize, forming ferric chloride and an oxychloride. The anhydrous chloride which is formed by passing hydrochloric acid gas over iron that is heated to redness, is a volatile, yellowish-white, very soluble solid.

Ferrous Iodide — Ferri Iodidum (Br.), (FeI_2) — is obtained in solution by adding an excess of iron to iodine suspended in warm water, until the solution is pale green.

Ferri Iodidum Saccharatum—Sacharated Ferrous Iodide (U. S. P.)—is made by reacting upon iron with iodine in the presence of water, evaporating the solution to dryness, and mixing with sugar of milk.

Syrupus Ferri Iodidi is also official. It contains about 10 per cent. of FeI_2.

Ferrous Oxide (FeO) is a black powder, produced by the reduction of ferric oxide by carbon. It easily oxidizes again.

Ferrous Hydroxide ($Fe(OH)_2$) is precipitated from ferrous solutions, by alkaline hydroxides, as a white powder. It also oxidizes readily, becoming green, and then brown.

Ferrous Sulphate—Protosulphate of Iron—Green Vitriol—Copperas—Ferri Sulphas (U. S. P., Br.), ($FeSO_4.7H_2O$)—is obtained pure by dissolving iron in dilute sulphuric acid.

$$Fe + H_2SO_4 = FeSO_4 + H_2.$$

For commercial use it is obtained from **pyrites** (FeS_2) by oxidation, and as a by-product in other processes. It forms oblique rhombic prisms. At a red heat it decomposes into ferric oxide, and sulphur di- and trioxides. On this property is based the production of fuming, or **Nordhausen sulphuric acid.**

Green vitriol has an extended use in the arts. Among other uses, it is employed in the manufacture of ink, and as a mordant in dyeing.

Ammonio-ferrous Sulphate ($Fe(NH_4)_2(SO_4)_2.6H_2O$) is a green, crystalline salt resembling the sulphate. It is more stable than ferrous sulphate.

Ferrous Carbonate ($FeCO_3$) exists in the mineral, **siderite.** It may be obtained by adding sodium carbonate to ferrous solutions.

$$FeSO_4 + Na_2CO_3 \rightarrow FeCO_3 + Na_2SO_4.$$

It is rapidly changed to ferric hydroxide on exposure to the air; is insoluble in pure water, but soluble in water containing carbon dioxide, and is, therefore, present in many natural waters.

Ferri Carbonas Saccharatum (U. S. P.) is ferrous carbonate to which sugar has been added to prevent decomposition, and is prepared by mixing solutions of ferrous sulphate and sodium bicarbonate and adding sugar: the mixture is then evaporated to dryness. It is a greenish gray powder.

Ferrous Phosphate Triferrous Phosphate ($Fe_3(PO_4)_2$) is a white precipitate formed by adding sodium phosphate to a solution of a ferrous salt. It turns blue on exposure to the air, a part being converted into ferric phosphate. It is insoluble in water; but slightly soluble in water containing carbon dioxide or acetic acid. A soluble or acid phosphate exists in the shops. A phosphate of iron that turns blue on exposure to the air, exists in the lungs in phthisis, in bones which have been buried for some time, and occasionally in pus.

Ferrous Sulphide Protosulphide (FeS) may be obtained, first, by fusing a mixture of sulphur and iron filings, although the union will often occur slowly at ordinary temperatures; second, by the precipitation of a ferrous salt with alkaline sulphides. The first method forms brownish, brittle, fusible masses, the latter yields a black powder. Ferrous sulphide is not decomposed by heat, but is decomposed by sulphuric acid, with the formation of ferrous sulphate and hydrogen sulphide. It occurs in the fæces of persons taking chalybeate waters and preparations of iron.

Ferrous Lactate Ferri Lactas (U. S. P.) ($Fe(C_3H_5O_3)_2, 3H_2O$) is obtained by dissolving iron filings in lactic acid. It forms light yellow crystals, soluble in water, and insoluble in cold alcohol.

Ferrous Oxalate (FeC_2O_4) is made by dissolving iron in a solution of oxalic acid. It is a bright yellow, crystalline powder, slightly soluble in hot water.

Ferrous Tartrate ($FeC_4H_4O_6$) is formed by dissolving iron in a hot, strong solution of tartaric acid.

Ferric Compounds.—Ferric Chloride—Sesquichloride of Iron—Perchloride of Iron—Ferri Chloridum (U. S. P.), (Fe_2Cl_6)—may be obtained in anhydrous, volatile, deliquescent plates, by heating iron in chlorine gas. It may be formed in solution by dissolving iron in hydrochloric acid and adding a little chlorine water or nitric acid; or by dissolving the oxide or hydroxide in hydrochloric acid; or by the action of chlorine on a solution of ferrous chloride. To obtain the solid, it is only necessary to evaporate and crystallize.

It forms yellow, crystalline masses or rhombic plates, readily soluble in water, alcohol, or ether.

The **Liq. ferri chloridi** (U. S. P.), or **Liq. ferri perchloridi** (Br.), is an aqueous solution containing an excess of acid.

The U. S. P. preparation contains 37.8 per cent. of ferric chloride.

The **Tinct. ferri chloridi** (U. S. P.) is the same, diluted with alcohol, and contains also ethyl chloride and ferrous chloride. It contains about 13.6 per cent. of Fe_2Cl_6.

Ferric Oxide—Sesquioxide of Iron (Fe_2O_3) exists in nature as hæmatite, and may be formed by heating the oxygen compounds of iron in the air. On a large scale, it is obtained by distilling ferrous sulphate, which first turns white, from loss of water; then yellow, owing to the formation of an oxhydrate, and finally to a brick-red ferric oxide. It is used as a polishing material, under the names of **colcothar, red crocus, jeweller's rouge,** or **caput mortuum.**

Ferrous-ferric Oxide ($Fe_3O_4 = FeO.Fe_2O_3$) occurs native as **magnetite.** It may be obtained artificially by conducting steam over ignited iron. It constitutes the natural magnets.

Ferric Hydroxide—Ferri Oxidum Hydratum (U. S. P., Br.), ($Fe_2(OH)_6$)—is a voluminous, reddish-brown, gelatinous mass, precipitated by alkaline hydroxides from ferric solutions. When dried at 100° C. (212° F.), it loses $2H_2O$. Freshly precipitated ferric hydroxide is soluble in a solution of ferric chloride or acetate, and if such a solution be dialyzed, the iron salt diffuses, leaving the pure ferric hydroxide on the dialyzer. The **dialyzed** iron so obtained is coagulated by heat, acids, or alkalies into a jelly-like mass. It is a good antidote in arsenic poisoning.

Ferric Sulphate ($Fe_2(SO_4)_3$) is obtained by dissolving the oxide in sulphuric acid. It remains, after evaporating the solution, as a white mass, which dissolves readily in water, forming the **Liquor ferri tersulphatis** (U. S. P.). This solution is a dark, reddish-brown liquid, having an acid, styptic taste. Another sulphate, which is basic, is formed by treating ferrous sulphate, 77 parts, with nitric acid, and evaporating, after adding 7 parts sulphuric acid.

This, in solution, is the **Liq. ferri subsulphatis,** or **Monsel's solution,** $Fe_4O(SO_4)_5$.

Ferric Alum—Ammonio-ferric Alum—Ferri et Ammonii Sulphas (U. S. P.), ($(NH_4)_2Fe_2(SO_4)_4.24H_2O$)—is prepared by adding a solution of ammonium sulphate to a solution of ferric sulphate, and evaporating down and allowing it to crystallize. The crystals are colorless or pale amethyst, regular octahedra, soluble in 3 parts of water at 15° C. (59° F.). The solution has an acid reaction and an astringent taste, but not so astringent as ferric sulphate. It gives the reactions for ferric iron, ammonia, and sulphates. It is employed in medicine as an astringent, both internally and locally.

Ferric Nitrate ($Fe_2(NO_3)_6$) is formed, together with ferrous nitrate, by dissolving iron in nitric acid. The **Liq. ferri nitratis** (U.S. P.), or **Liq. ferri pernitratis** (Br.), is an aqueous solution of ferric nitrate, containing about 6.2 per cent. of $Fe_2(NO_3)_6$. Ferric nitrate crystallizes in rhombic prisms with $18H_2O$, or in cubes with $12H_2O$.

Scale Compounds of Iron.—These are certain salts of iron, mostly with organic acids, which do not crystallize readily, but are put into the market in the form of thin scales. They are prepared by evaporating their solutions to a thick, syrupy consistence, spreading upon glass plates, drying, and then detaching the thin scales from the glass. They are all used in medicine.

Ferri Citras (U. S. P.)—citrate of iron—is prepared by dissolving freshly precipitated ferric hydroxide in a solution of citric acid, and evaporating the solution to the proper consistency and scaling. After its aqueous solution has been evaporated upon glass, it forms beautiful, thin, transparent scales, of a garnet-red color, slowly soluble in cold, but freely in hot water, and possessing a mild, chalybeate taste.

Ferri et Ammonii Citras (U. S. P.)—citrate of iron and ammonia—is formed by treating a solution of citrate of iron with ammonium hydroxide, and evaporating at a temperature that should not exceed 60° C. (140° F.).

It also forms garnet-red scales, which are readily and wholly soluble in water, forming a solution that is neutral to litmus paper and slightly styptic in taste.

Ferri et Ammonii Tartras (U. S. P.)—tartrate of iron and ammonia, a double salt—is formed by the action of tartaric acid upon ferric and ammonium hydroxides. Upon evaporating the solution, garnet-red scales remain, which are slowly soluble in water. Their solution is neutral to test paper, and is of a sweetish, rather pleasant taste.

Ferri et Potassi Tartras (U. S. P.)—**Ferrum Tartaratum** (Br.)—**potassio-tartrate of iron**—may be obtained by dissolving ferric hydroxide in a solution of acid tartrate of potassium, and evaporating on glass. It forms ruby red scales, having about the same properties as the ammonio tartrate.

Ferri et Quiniæ Citras (U. S. P., Br.)—citrate of iron and quinine—contains citric acid, ferric hydrate, and quinine citrate. It is prepared by adding quinine and a little citric acid to a solution of ferric citrate, and evaporating. It forms transparent scales of a greenish tint, slowly soluble in cold water, but freely in hot water, forming bitter, slightly styptic solutions.

Ferri et Strychniæ Citras closely resembles the citrate of iron and ammonia in appearance, but has a bitter taste, and gives a white precipitate with ammonium hydroxide. It is prepared by adding a solution of strychnine citrate to a solution of citrate of iron and ammonium, evaporating on a water bath to a syrup, and drying on glass.

Ferri Phosphas (U. S. P., Br.), ($Fe_2(PO_4)_2$).—Phosphate of iron occurs as the result of a double decomposition between ferric sulphate and sodium phosphate. It forms a bright, slate-colored powder, insoluble in water, but soluble in acids.

Ferri Pyrophosphas (U. S. P.), ($Fe_4(P_2O_7)_3$).—Pyrophosphate of iron is formed by adding a solution of sodium pyrophosphate to a solution of a ferric salt. It does not crystallize, but forms scales upon evaporating its solution. These are thin, apple-green in color, turn dark on exposure to the air, and are soluble in water, but not in alcohol. Ammonium hydroxide produces no precipitate in its solution, but sodium hydroxide does. The official salt contains 48 per cent. of anhydrous ferric pyrophosphate.

NICKEL.

Ni = 58.7.

Occurrence, Preparation, and Properties.—This metal is found native in meteorites. Its most common ores are **Nic-**

colite (Ni_2AS_2) and **Nickel Glance** ($NiAs_2NiS_2$). These ores of nickel, however, usually also contain cobalt, and the cobaltous ores are also commonly nickel-bearing. The separation of nickel from its ores is a very complicated process, and for an account of it, the reader is referred to works on metallurgy. Nickel may be prepared chemically pure by igniting its oxalate or carbonate in a stream of hydrogen. This metal is silver white, tenacious, and very lustrous. Sp. gr. 8.9. It is attracted by the magnet. It does not alter in the air, but dissolves in the mineral acids, especially nitric.

Compounds.—The following are the most common of the nickel compounds; they are mostly **ous** compounds, having the general form NiR_2, and all possess a green color: **nickelous hydroxide** ($Ni(OH)_2$), **nickelous chloride** ($NiCl_2.6H_2O$), **nickelous cyanide** ($Ni(CN)_2$), **nickelous sulphate** ($NiSO_4.7H_2O$), and **nickelous sulphide** (NiS). **Nickelic oxide** (Ni_2O_3) and **hydroxide** ($Ni_2(OH)_6$) exist, and are similar to the corresponding cobalt compounds. Nickel is used largely in certain alloys and for electro-plating.

COBALT.

Co = 59.5.

Occurrence, Preparation, Properties, etc.—**Smaltite** ($CoAs_2$) and **cobaltite** ($CoAs_2.CoS_2$) are the most commonly occurring native ores of cobalt. It is prepared in the same manner as nickel. It is a white metal, tenacious, and fusible with great difficulty; sp. gr. 8.9. Its other properties are very similar to those of nickel.

Cobalt Compounds are also chiefly **ous**, corresponding to the general form CoR_2. Those containing water have a reddish color; the anhydrous compounds are blue.

The cobaltous compounds are **cobaltous chloride** ($CoCl_2$), **cobaltous hydrate** ($Co(HO)_2$), **cobaltous sulphate** ($CoSo_4.7H_2O$), **cobaltous nitrate** ($Co(No_3)_2.6H_2O$), and **cobaltous sulphide** (CoS).

The cobaltic compounds are **cobaltic oxide** (Co_2O_3) and **cobaltous-cobaltic oxide** ($Co_3O_4 = Co_2O_3.CoO$.) The latter corresponds to magnetite (Fe_3O_4).

The last six elements of **group viii** are usually classed as "metals of the platinum ores," or the **platinum group of metals.** The platinum ore, or crude alloy, occurs in small metallic grains in sands of a few regions, chiefly in the Ural

Mountains, Brazil, and Ceylon. These metals all form hydroxides (or salts representing them) having acid properties, and therefore play both the positive and negative rôle. Platinum is the only one used to any extent in the metallic condition.

PLATINUM.

Pt = 195.

Occurrence, Properties, etc.—It exists in nature associated with the other members of the group; also, in ores containing gold, lead, silver, and iron.

It is a lustrous, white metal; sp. gr. 21.5. It is very tenacious, malleable, ductile, and is capable of being drawn out into very fine wire. At high temperatures it softens without melting; it fuses at about 1770° C. (3218° F.). Upon heating the double chloride of platinum and ammonium, it decomposes, leaving a grayish-black, spongy mass called **platinum sponge.** This latter has the property of absorbing great quantities of certain gases. A jet of hydrogen projected upon it, readily inflames by the condensation and oxidation of the hydrogen in the pores of the sponge, the heat developed being sufficient to ignite the hydrogen. Platinum is not affected by the air or oxygen. It unites with chlorine, arsenic, silicon, sulphur, and phosphorus. It does not dissolve in the single acids, and is only soluble in liquids generating free chlorine, as aqua regia. With many heavy metals it forms easily fusible alloys. Therefore, easily reducible metallic oxides, as those of arsenic, lead, etc., ought never to be ignited in platinum vessels. Platinum is valuable for its high fusing point and its power to withstand oxidation. It is expensive, because of its scarcity.

Platinum Compounds.—These are of two series, platinous, PtR_2, and platinic, PtR_4. In the first, the metal is more basic, and in the latter, more negative in nature.

Platinum Tetrachloride ($PtCl_4$) is obtained by dissolving platinum in aqua regia and evaporating off the nitric acid. On evaporating, it crystallizes in soluble, reddish-yellow needles. With ammonium or potassium chloride, and the alkaloids, it forms characteristic double chlorides. It is largely used as a reagent to precipitate potassium, ammonium, or the alkaloids, for quantitative estimation.

OSMIUM.

Os = 190.8.

This rare metal, occurring with some of the other platinum metals, is mentioned here for the sake of its oxide (OsO_4), which has received considerable attention as a staining agent. The metal resembles platinum.

The tetroxide (OsO_4) (so-called **osmic acid**) may be prepared by glowing the metal in air, or by the action of chlorine and moisture upon osmium. The oxide occurs as lustrous, transparent, yellow needles having a very irritating, piercing odor, and is intensely poisonous. It has been used to arrest the motions or to kill the organisms in water for microscopical examination.

Many kinds of organic substances reduce this oxide and precipitate the metal, and it is due to this property that it has found use as a staining agent in histology, to bring out delicate structures.

Osmic acid has been employed as a remedy in neuralgia, goitre, scrofulous ulcers, and in epilepsy, in doses of $\frac{1}{50}$ grain.

PART IV.

ORGANIC CHEMISTRY.

Carbon and Hydrogen.—The substances derived from the animal and vegetable kingdoms are composed principally of four elements; carbon, hydrogen, oxygen, and nitrogen, with occasionally sulphur and phosphorus. Few as are the chemical elements concerned, the number of the compounds of these elements is almost endless. Formerly only those substances directly or indirectly derived from bodies possessing vegetable or animal life were considered as organic; but as our knowledge increased, a large number of compounds were prepared in the laboratory from these bodies, which were identical with others prepared by plants and animals themselves. It was thus demonstrated that by pure chemical agencies many of the products of living organisms could be prepared, and that a vital principle was not necessary to form these compounds; and also that by the same chemical action a great many compounds could be formed which could not be found in either animal or vegetable organisms. This greatly enlarged the field of investigation, and a new meaning was attached to the term **organic chemistry.** It was found necessary to extend the science to include all bodies in any way resembling organic compounds, either in composition or properties; *i. e.*, all compounds containing carbon and hydrogen. Carbon and hydrogen are the indispensable elements to the formation of organic bodies; without these we can have no substance capable of vegetable or animal life. In the great majority of organic compounds we also have oxygen or nitrogen, or both.

Organic Chemistry may be defined as that branch of the science of chemistry which treats of the carbon compounds containing hydrogen, either alone, or with oxygen, nitrogen, sulphur, phosphorus, etc.

While inorganic compounds, as a rule, contain but a few atoms, organic compounds frequently contain a large number; and the diversity in organic chemistry is obtained, not alone by varying the kind of atoms, but by varying the arrangement of a few kinds. There exist, however, certain organized bodies which possess a structure entirely different from that of any known inorganic body or artificial organic substance. These *organized* structures are the sole product of vital action, and cannot be produced in the laboratory. Such bodies are seen in the cell of living organisms; and although we may be able at some time to construct molecules identical with those composing them, we shall never be able to impart that function of growth, reproduction, and other vital processes which we call life. The complexity of organic compounds may readily be attributed to the inherent properties of carbon, the leading or most characteristic element of which they are composed. The atoms of carbon exhibit, in a remarkable degree, a tendency to combine themselves into groups or chains, around which the other atoms or groups of atoms are arranged.

Qualitative Examination of Organic Bodies.—Organic bodies may usually be distinguished from inorganic by their behavior when heated. Organic bodies are either volatilized when moderately heated, or decomposed into certain volatile products, leaving a black char behind them. When strongly heated in the air they take fire and burn. Those which distil unchanged, deposit carbon when their vapor is conducted through a red-hot tube.

Carbon.—The best proof of the **presence of carbon** in the organic substance is given by burning it in an atmosphere of oxygen, or by heating it dry with CuO and collecting the CO_2 evolved. The presence of CO_2 may be shown by passing the gas from the combustion through a solution of lime water.

The **quantitative estimation of carbon** is conducted on the same principle, but the CO_2 is absorbed by a solution of potassium hydroxide contained in a U-tube, and weighed before and after the experiment. The difference in these weights gives the weight of CO_2, from which the carbon may be calculated. This operation is conducted in a specially constructed furnace. The substance to be analyzed is mixed with the oxide of copper in a hard glass tube, which is then heated in the furnace shown in Fig. 60 by a row of gas burners.

The watery vapor and CO_2 are passed through a previously weighed tube, containing dry $CaCl_2$, which absorbs all the water. The CO_2 passes on and is absorbed by the solution of potassium hydroxide contained in the series of bulbs in the next tube, seen at the right of the furnace. When the combustion is complete, air is drawn through the apparatus, by the aspirator bottle shown at the right of the furnace. The air is first freed from moisture and CO_2, by passing through the train of jars shown at the left of the furnace. The increase in weight of the tube containing the $CaCl_2$ and that containing the KOH, gives the H_2O and CO_2 respectively, from which the hydrogen and carbon producing them may be calculated. The oxygen in organic compounds is always determined by the difference between the sum of the other elements and the weight taken.

Nitrogen may be tested for by burning the substance in the air, when, if nitrogen be present in more than traces, it will give off an odor like that of burning feathers or horn. Some organic substances containing nitrogen, on being heated, explode. Another method of testing for nitrogen is to heat the substance with potassium hydroxide and lime in powder, when ammonia is evolved. This may be detected by its odor, its reaction with moistened litmus paper, or fuming HCl.

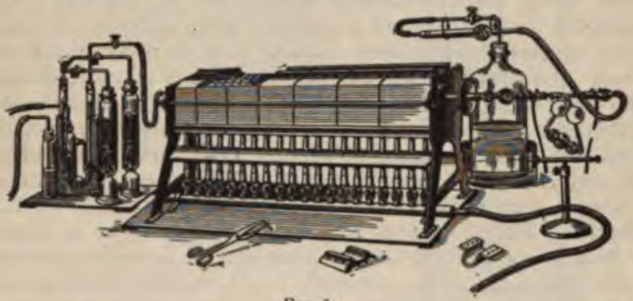


FIG. 60.

Sulphur may be detected in many cases by heating the substance with a strong solution of potassium hydroxide, and adding a solution of a lead salt, which is turned black on burning if sulphur be present. Another method of testing for sulphur: **Solids** are fused with two parts of potassium hydroxide and one of potassium nitrate. After collecting, the mass is dissolved in water, HCl added, and sulphates tested for with $BaCl_2$. **Liquids** are treated with fuming HNO_3, or a mixture of HNO_3 and $KClO_3$ with a gentle application of heat. The solution may then be tested for sulphates as above.

The **halogens** may be detected by heating the substance with lime, afterward dissolving in water, acidifying with HNO_3, and adding a solution of $Hg_2(NO_3)_2$. The halogens are precipitated either as Hg_2Cl_2, Hg_2Br_2, or Hg_2I_2.

Phosphorus may be detected by fusing the substance with KNO_3 plus KOH, dissolving in water, and testing for phosphoric acid.

THE PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS.

The physical examination of an organic compound includes the determination of its solubility in various menstrua, the fusing point, the boiling point, the vapor density, the freezing point of its solutions if non-volatile, its crystalline form and its optical behavior in the polariscope.

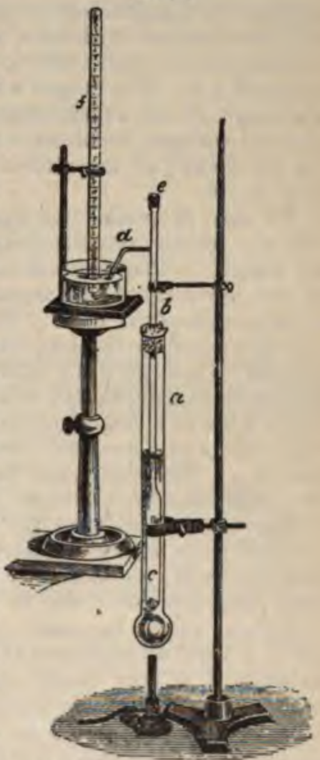
Fusing Point.—When pure, the fusing point of organic compounds is fairly constant. Some of these compounds, however, decompose before reaching their fusing points.

The fusing point is usually determined by placing a small quantity of the substance in a capillary tube, made by drawing off a piece of glass tubing after heating it in the flame of a Bunsen burner. This tube is now fastened to the side of a thermometer by a rubber band, so that the substance is opposite the bulb of the thermometer. The thermometer and capillary tube are then placed in a bath of water, or paraffin, contained in a beaker or flask, and the bath is gradually heated. When the substance melts, the temperature of the bath is noted.

Boiling Point.—Most organic liquids boil at a constant temperature, and without decomposition. A mixture of different liquids does not have a constant, but a variable boiling point. The boiling point at a constant atmospheric pressure is one of the most important means of determining the purity and the identity of an organic compound. The boiling points of organic liquids serve to separate one from another having a higher or lower boiling point, by the process known as fractional distillation. In this process, the mixed liquids are placed in a retort or distilling flask with a thermometer suspended above the liquid; heat is now applied to the retort and the distillates coming over at fixed intervals of temperature are collected separately. By repeating the process, the liquids may finally be separated. The boiling point of a liquid is determined by placing it in a distilling flask, or retort, and suspending a thermometer through a perforated cork in the neck of the flask so that the bulb is just above the surface of the liquid. That is, we determine the temperature of the escaping vapor.

Vapor Density.—The vapor density of volatile organic compounds affords an easy and certain means of determining their molecular weights. By page 84, we have seen that the molecular weight of any body is twice its density in the gaseous state, or the density of a gas or vapor is half its molecular weight. The easiest way of determining the vapor density of a substance is that known as Victor Meyers'.

FIG. 61.



VICTOR MEYERS' APPARATUS.

The apparatus (represented by Fig. 61), consists of an outer tube of glass (*a*), the bulb of which contains water or other fluid which has a constant and known boiling point. The inner tube (*b*) contains air, is stoppered at the upper end, and is provided with a delivery tube (*d*) to allow the escape of the air, as it is heated by the vapor of the boiling fluid in the outer tube.

The open end of this tube is placed in a cup, under water, while the water is being boiled. As soon as the air ceases to escape from the delivery tube, the cork is removed from the top of the inner tube (*b*), and a small vial containing a weighed amount of the liquid to be examined is dropped in and the cork quickly inserted. The heat boils the liquid, forces out the stopper in the vial, and the vapor thus produced drives out an equal volume of air through the delivery tube.

This air is collected in the graduated tube (*f*), previously placed over the open end of the delivery tube, and carefully measured.

The volume of air obtained, represents the volume of the vapor at the temperature of boiling water or of the liquid used in the outer tube. The true volume under standard conditions is now to be calculated by the formula given on page 19. Practically, this correction is usually made by reference to tables prepared for the purpose.

The volume of the vapor of a liquid of known weight having been determined, we may easily calculate the density. For example, suppose 0.1 grm. of alcohol be taken, and we find 48.5 c.c. of air after making the necessary corrections. Now, 0.1 grm. of hydrogen measures 1116 c.c. at 0° C and 760 mm. pressure. We now compare these volumes and we have $\frac{1116}{48.5} = 23$, or the hydrogen occupies 23 times the volume of an equal weight of alcohol vapor. Or, one litre of hydrogen under standard conditions weighs 0.0896 grm., a crith. One c.c. of hydrogen then weighs .0000896 grm.; 48.5 c.c. of hydrogen will weigh .0043956 grm. By dividing the weight of the alcohol taken, 0.1 grm., by the weight of 48.5 c.c. of hydrogen, we obtain 23 as the density of the alcohol vapor. As the density of the alcohol vapor is 23, its molecular weight must be 46.

We may determine the molecular weight of substances that will not wholly volatilize without decomposing, by the method of Raoult. This method consists in determining the amount of the lowering of the freezing point of a solvent, due to the substance dissolved in it. The lowering of the freezing point is proportional to the quantity of the solid in solution. While this law is not perfectly uniform for inorganic substances, it is uniformly so with organic substances with a very few exceptions. Let 1 gram of a compound be dissolved in 100 grams of a liquid with which it forms no chemical union. Let the molecular weight of this compound be represented by M. If we now cause the solution to freeze, we shall observe that it freezes at a lower temperature than the solvent. This depression of the freezing point we will represent by D. If we multiply this depression by M, the molecular weight of the compound, we shall have the depression for M grams of the substance; *i. e.*, the molecular weight expressed in grams. Let this be represented by T. Then we shall have $D \times M = T$. Raoult found that the value of T is very nearly constant for the same solvent. The value of T for water is 19, for acetic acid 39, for benzene 49. Now, as D is determined by experiment, and T is constant, M may be easily calculated by dividing T by D, or $M = \frac{T}{D}$. For example, a solution of glucose containing 10 grams to 100 grams of water was placed in a beaker of 400 c.c. capacity, and provided with a three-holed cork, one hole for the thermometer and one for the stirring rod. It was cooled to — 2° C. A crystal of ice from a similar solution was dropped in to make it freeze. The thermometer rose to — 1.06° C. The depression due to 1 gram was then one-tenth of this, or 0.106° C. Hence, $19 \div 0.106 = 179$ as the molecular weight of glucose. Analysis gives us the empirical formula, $CH_2O = 30$. By multiplying this number by 6 the result is 180, which is near enough to determine that as its formula, instead of any other multiple of 30. The slight difference here is within the limits of experimental error.

To deduce the formula from analysis. Rule: Divide the percentage of each element by its atomic weight, and express the ratio of these quotients in their lowest terms.

Analysis of Alcohol.

$C = 52.16.$
$O = 34.80.$
$H = 13.04.$
$52.16 \div 12 = 4.34$ atoms of carbon.
$34.80 \div 16 = 2.17$ atoms of oxygen.
$13.04 \div 1 = 13.04$ atoms of hydrogen.
Ratios, C 4.34, O 2.17, H 13.07.
Lowest terms, C 2, O 1, H 6.

As per cent. is equivalent to parts in one hundred, we may calculate the amount of carbon in each molecule by the following proportion: $100 : 46 :: 52.16 : 23.99$; or in 46 parts of alcohol there are approximately 24 parts of carbon.

For oxygen we have $100 : 46 :: 34.80 : x = 16.008$.

For hydrogen we have $100 : 46 :: 13.04 : x = 5.998$. The atomic weight of carbon is known to be 12, or each molecule contains 2 atoms of carbon. As the atomic weight of oxygen is 16, each molecule contains one atom of oxygen. As the atomic weight of hydrogen is 1, each molecule of alcohol contains 6 atoms of hydrogen.

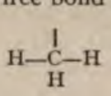
The molecular formula of alcohol is C_2H_6O, making the molecular weight 46. The vapor density of alcohol we found above to be 23, its molecular weight, therefore, is 46.

DETERMINATION OF THE CONSTITUTION OF ORGANIC COMPOUNDS.

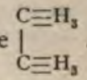
This is possible only when we know the behavior of the compound with reagents. This may be illustrated as follows: When we treat an ethereal solution of CH_3I with sodium we set free the **methyl.**

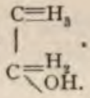
$$CH_3I + Na = CH_3 + NaI.$$

This CH_3 must have one free bond of attraction, thus:

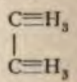


$$\begin{array}{c} | \\ H\text{—}C\text{—}H \\ H \end{array}$$

The vapor density of this gas is ·15 The molecular weight, therefore, is 30, or corresponds to C_2H_6; *i. e.*, the two methyl radicals unite by their free bonds, and we have  $\begin{array}{l} C\equiv H_3 \\ | \\ C\equiv H_3 \end{array}$.

By treating C_2H_6 with chlorine we form C_2H_5Cl. This treated with KOH gives C_2H_5OH, or **ethyl alcohol.** As OH has taken the place of Cl in C_2H_5Cl, we conclude that the OH has gone in as hydroxyl. This atom of hydrogen can be replaced with sodium or potassium, but none of the others in the molecule can be. This atom, therefore, has a different position in the molecule from the others. The relation of the carbon atoms is not destroyed by the above reaction, and therefore we arrive at the conclusion that the formula is  $\begin{array}{l} C\equiv H_3 \\ | \\ C{=}H_2 \\ \;\diagdown OH. \end{array}$ Again, we have the reactions,

$$C_2H_6O + HCl = C_2H_5Cl + H_2O.$$

i. e., we have the C_2H_5 and OH groups in alcohol. And again, if we treat C_2H_5Cl with nascent hydrogen, we obtain C_2H_6 and HCl. C_2H_6 we have seen above to be **di-methyl, or**  $\begin{array}{l} C\equiv H_3 \\ | \\ C\equiv H_3 \end{array}$.

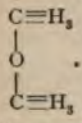
In **methyl ether,** which is isomeric with alcohol, no one of the hydrogen atoms can be replaced with sodium or potassium. When we remove the oxygen atom with HI the connection of the carbon atoms is broken, with the formation of compounds having one carbon atom only. Thus:

$$C_2H_6O + HI = CH_4O + CH_3I,$$

or

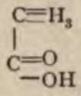
$$C_2H_6O + 2HI = 2CH_3I + H_2O.$$

This shows that the oxygen atom in methyl ether acts as a link between the two carbon atoms, as its removal breaks the molecule apart; also that the hydrogen atoms are all alike in the molecule. Hence, the formula would be represented as follows:



$\begin{array}{l} C\equiv H_3 \\ | \\ O \\ | \\ C\equiv H_3 \end{array}$

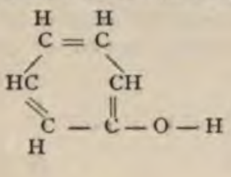
. The formula of **alcohol** would be represented as follows: CH_3-CH_2OH. In the same way we determine that the rational formula of **acetic acid** is

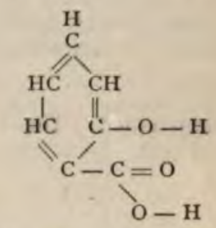


$\begin{array}{l} C\equiv H_3 \\ | \\ C{=}O \\ \quad -OH \end{array}$

.

It is the aim of chemists to follow out such reactions, for all organic bodies to determine the rational formula. This has been done for most organic substances. When we know the structure of the molecule of the substance we are able in many cases to construct it synthetically. Thus, if we compare the following formulæ, we see a close resemblance:

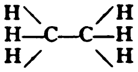




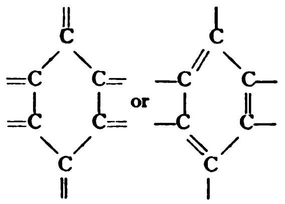
If we treat the first of these substances with sodium hydroxide, we obtain C_6H_5ONa. If we treat this at a high temperature with CO_2, this gas enters the molecule, CO going in with the NaO group to give C_6H_5COONa. The other O goes to the neighboring carbon atom and gives OH. Thus **salicylic acid** is prepared from carbolic.

The atoms of carbon exhibit, in a remarkable degree, a tendency to combine themselves into groups or chains, around which the other atoms or groups of atoms are arranged. In other words, the carbon atoms are the skeleton in and upon which a very complex structure may be built. The underlying principle of organic chemistry is the grouping of the carbon atoms, and upon these groups the whole superstructure is based.

Hydrocarbons.—Carbon Nuclei.—Carbon is a tetrad and can combine with four monads. As has been said, it can also unite with another carbon atom, and the two atoms thus united will combine with six monad or hydrogen atoms:

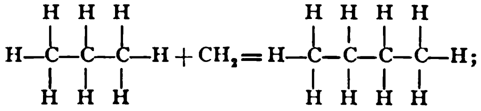


Three, four, five, or any number (n) atoms of carbon may thus unite, theoretically at least, and give rise to a chain of atoms, which has been called an **open chain.** Again, the same atoms may combine as follows:

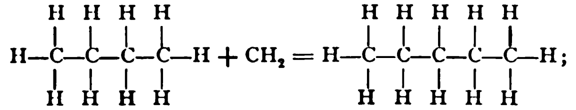


giving rise to **closed chains, or cycles.**

By a little consideration, it will be seen that, in either of the first two formulæ given above, if we increase the carbon atoms in any given formula, we also increase the number of **bonds**, or points of contact for hydrogen atoms, by two for every carbon atom added. Thus:



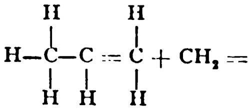
$$\mathrm{H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}H + CH_2 = H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}H;}$$



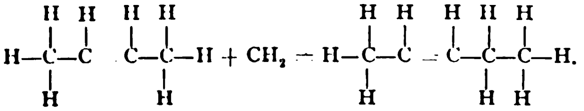
$$\mathrm{H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}H + CH_2 = H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}H;}$$

and so on.

We thus have a series of hydrocarbons differing from each other by the constant quantity of CH_2. Such a series is called a **homologous series.** In the same chain of carbon atoms, we might have the following arrangement of the bonds of attraction:—



$$\mathrm{H{-}\overset{H}{\underset{H}{C}}{-}\underset{H}{C} = \overset{H}{\underset{H}{C}} + CH_2 =}$$



$$\mathrm{H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{C}\quad \overset{H}{C}{-}\overset{H}{\underset{H}{C}}{-}H + CH_2 = H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{C} = \overset{H}{C}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}H.}$$

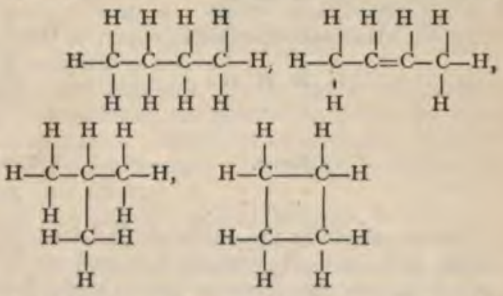
This gives rise to another homologous series, each member differing from the corresponding member of the series above mentioned by the constant quantity of H_2, and known as the **isologous series.** In the vertical columns of the following table we have the **homologous series;** in reading from left to right, we have the **isologous series** of hydrocarbons.

CH_4	CH_2*	C*	
C_2H_6	C_2H_4	C_2H_2	
C_3H_8	C_3H_6	C_3H_4	C_3H_2
C_4H_{10}	C_4H_8	C_4H_6	C_4H_4
C_5H_{12}	C_5H_{10}	C_5H_8	C_5H_6
C_6H_{14}	C_6H_{12}	C_6H_{10}	C_6H_8
C_7H_{16}	C_7H_{14}	C_7H_{12}	C_7H_{10}
C_8H_{18}			
C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	C_nH_{2n-4}

This table does not by any means represent all the possible compounds, but gives an idea of how all known hydrocarbons may be classified, by extending the table.

The members of these series having but a few carbon atoms in their molecules are termed the lower members, and those having a higher number of carbon atoms, the higher members.

Isomerism Polymerism.—Besides the method of grouping the carbon nuclei which we have indicated, a variety of other methods may be conceived, some of which really exist. Thus the group containing four carbon atoms may be arranged as follows:



The first and third of these would have the same number of atoms and the same formula, C_4H_{10}, but would have different physical and chemical properties. Compounds having the same chemical composition but possessing different properties, are termed **isomeric bodies.** The same may be said of the second and fourth of the above formulæ: the empirical formula is C_4H_8, but they are quite different in the *constitution* of their molecules, while they are the same in *composition.* These two compounds are isomeric. The chemical and physical properties of organic compounds depend not only upon the kind and number of atoms, which is designated the **composition** of the molecule, but also upon the arrangement of the atoms in the molecule, or the **constitution.** It is in this way that we may have several compounds, each answering to the same formula, and giving the same result on analysis, but totally different in properties. We may mention here as examples, ammonium cyanate, NH_4OCN, and urea, $CO\begin{cases}NH_2\\NH_2\end{cases}$.

---

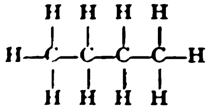
* Unknown.

Also,

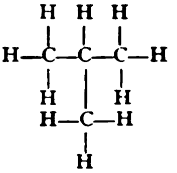
$$N\begin{cases}C_3H_7\\H\\H\end{cases}\qquad N\begin{cases}CH_3\\C_2H_5\\H\end{cases}\qquad N\begin{cases}CH_3\\CH_3\\CH_3\end{cases}$$

Propylamin. Methyl-ethylamin. Trimethylamin.

In those members of the above series of hydrocarbons having four or more carbon atoms, we may have several isomers. The number of these isomers increases rapidly with the increase of the carbon atoms. Thus, there are two possible butanes, known as butane and iso-butane or methyl-propane.



Butane.



Methyl-propane
or
Iso-butane.

As we ascend in the series, we find for C_5H_{12} three isomers, for C_6H_{14} five, for $C_{10}H_{22}$ seventy-five, and for $C_{11}H_{24}$ it has been computed that we may have no less than one hundred and fifty-nine isomers. This fact explains why we can have an indefinite number of compounds classified in the above table. This same law of isomers applies to the other homologous series, as well as to the first.

Polymeric bodies are compounds having the same percentage composition, but different molecular weights. We have a striking example of this property in the second column of the table above. Ethene, C_2H_4, Butene, C_4H_8, and Octene, C_8H_{16}, are polymeric bodies. Starch, cellulose, dextrin, and glycogen are probably polymeric bodies.

Nomenclature of Organic Compounds.—The nomenclature of organic compounds is complicated and unsatisfactory. The large number of compounds, and their endless derivatives to be considered, make it next to impossible to devise a system of naming them that shall meet with general approval. The result of the rapid advance in the discovery of organic compounds has been to produce confusion in this respect.

Certain compounds have received different names by different observers, and it is no unusual thing to meet with four or five synonymous names for the same compound. In consequence of this the whole subject of nomenclature is being revised by an International Commission, appointed by an International Congress of Chemists, which met at Paris in 1889.

The Commission has published, as the result of its deliberations, a preliminary report embracing sixty-two rules for naming organic compounds. These rules are, as yet, not generally adopted. It may be stated, however, that the nomenclature of organic compounds is in the transitional stage. We shall endeavor to follow the best usage in the naming of chemical compounds.

Organic Radicals.—In organic chemistry, as in inorganic, although to a greater extent, we are constantly dealing with certain well-defined groups of atoms, which retain their identity through a large series of compounds, and behave in chemical reactions like simple radicals or atoms.

It is evident that by removing one or more atoms of hydrogen from any saturated hydrocarbon, the remaining group of atoms may act as a compound radical; while the unsaturated hydrocarbons of the second or third series may act as radicals without the removal of any hydrogen atoms.

These hydrocarbon radicals are usually designated by the termination **yl**. Thus: CH_3 is known as methyl; C_2H_5, as ethyl; C_6H_5 as phenyl. These radicals are called, collectively, hydrocarbon or alcohol radicals, and the quality of their combining power is electro-positive.

The following radicals are frequently met with, and may with advantage be committed to memory by the student:

NOTE.—Metamerism is sometimes used as synonymous with isomerism.

[illegible]

[illegible] uniformity in nomenclature and [illegible] follow the best usage in [illegible]

The Paraffins. The paraffins are chemically indifferent bodies because they are fully saturated compounds. They are stable compounds, not easily attacked by reagents. They are not acted upon by alkalies or acids. Many of these hydrocarbons are found in petroleum and the gases accompanying it, and others are found in the products of the dry distillation of coal and other organic substances. They may also be prepared by one of the following reactions:

1. By treating an alkyl iodide with zinc at 160° C. in presence of water.

$$C_2H_5I + HOH + Zn = C_2H_6 + Zn\left\{\begin{matrix}OH\\ I\end{matrix}\right. .$$

2. By heating certain salts of the acids containing one or more carbon atoms. Thus, by heating calcium acetate with sodium hydroxide.

$$(C_2H_3O_2)_2Ca + 2NaOH = 2CH_4 + Na_2CO_3 + CaCO_3.$$

3. By the electrolysis of the acids of the acetic acid series.

The lower paraffins are gaseous, and insoluble in water. Those below butane are gases at ordinary temperatures, those between C_4H_{10} and $C_{16}H_{34}$ are liquids, and the higher members are solids. Alcohol dissolves the gases slightly, the liquids readily, and the solids with difficulty. The boiling point, the melting point, and the specific gravity increase with the increase of carbon atoms.

Methane, or **Marsh Gas,** CH_4.—This gas is a constant product of the decomposition of vegetable matter under water, and may frequently be seen rising to the surface of stagnant pools. It is produced by the dry distillation of coal, and is therefore a constituent of ordinary illuminating gas. It is the chief constituent of miners' "fire damp." It occurs in the gases of the intestines to the extent of from 25 to 50 per cent.

Natural gas is composed of from 90 to 95 per cent. of marsh gas, with small quantities of nitrogen and carbon dioxide.

Preparation.—Methane may be prepared by heating a mixture of 4 parts of sodium acetate, 4 parts of sodium hydroxide, and 6 parts of lime. It may be prepared synthetically by the following reactions: The electric arc in an atmosphere of hydrogen produces a small quantity of ethine. Ethine may also be produced by the reaction between calcium carbide and water. (See calcium carbide.)

$$C_2Ca + H_2O = C_2H_2 + CaO.$$

Ethine, when mixed with hydrogen and passed through a tube containing spongy platinum, forms ethane, $C_2H_6C_2H_2+2H_2= C_2H_6$.

Ethane passed through a heated tube gives the following reaction:—

$$2C_2H_6 = 2CH_4 + C_2 + 2H_2.$$

When a series of electric sparks are passed through a mixture of hydrogen and carbon oxide, CH_4 is prepared.

$$CO + 3H_2 = CH_4 + H_2O.$$

By these reactions the elements are made to yield CH_4 and C_2H_6, which can serve as the starting point in the synthesis of other organic compounds, and thus bridge over the gap between inorganic and organic compounds.

Properties.—Methane is a light, colorless, transparent, odorless, tasteless, combustible gas. Density = 8. Sp. gr. = 0.559. Under 140 atmospheres of pressure at 0° C. (32° F.), it condenses to a transparent liquid. It burns in the air with a bluish flame, giving no light but a high temperature. Mixed with air or oxygen, it forms an explosive mixture ("fire damp"). By passing the gas through a red-hot tube it is converted into carbon and hydrogen, with traces of C_2H_2, C_2H_4, C_2H_6, and $C_{10}H_8$. Mixed with Cl and diluted with CO_2 it forms chlorine substitution compounds, CH_3Cl, CH_2Cl_2, $CHCl_3$, and CCl_4.

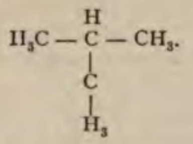
It is irrespirable, but not poisonous. Poisoning by house-gas containing CH_4 is produced by the other gases which it contains.

Ethane, or di-methyl ($CH_3—CH_3$) occurs in crude petroleum, and is a constituent of some of the natural gas wells of western Pennsylvania. The oil wells discharge large volumes of gas containing H, CH_4, and C_2H_6, which are used for heating and lighting in the neighboring districts. When crude petroleum is heated, the hydrocarbons, ethane, propane, and butane are evolved as gases. These are collected and subjected to condensation, yielding a liquid consisting chiefly of butane (C_4H_{10}), known as cymogene, which is used in ice machines.

Properties.—Ethane is a gas at ordinary temperatures, but is condensed to a liquid at a pressure of 46 atmospheres at 4° C. It burns with a faintly luminous flame. It is slightly soluble in water and alcohol.

Propane (C_3H_8) is present in crude petroleum, and is a liquid below −30° C. It may be prepared artificially by the action of hydriodic acid (HI) upon glycerin at 275° C.

Butane (C_4H_{10}) boils at 1° C. Its sp. gr. is 0.6, being the lightest liquid known. It is found in crude petroleum. This is the first paraffin in which we have an isomer, **isobutane,** containing one side chain.



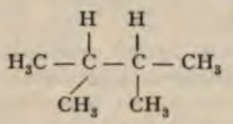
$$\begin{array}{ccccc} & & H & & \\ H_3C & - & C & - & CH_3. \\ & & | & & \\ & & C & & \\ & & | & & \\ & & H_3 & & \end{array}$$

This compound boils at —17° C.

The **normal paraffins** are regularly formed compounds, in which each C atom is linked to two other C atoms.

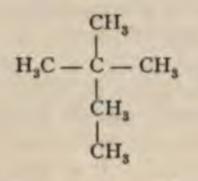
In the **isoparaffins** one carbon atom is linked to three others, as in butane above.

In the **neoparaffins** two carbon atoms are each linked to three others.



That is, in the iso-compounds we have one side chain; in the neo-compounds we have two side chains.

In the **mesoparaffins** one carbon atom is linked to four others.



$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ H_3C & - & C & - & CH_3 \\ & & | & & \\ & & CH_3 & & \\ & & | & & \\ & & CH_3 & & \end{array}$$

PETROLEUM.

The higher members of this series are found in American petroleum, and may be isolated to a great extent by careful fractional distillation. The distillation of petroleum is carried on on a large scale in certain parts of this country, and a variety of products are found in the market, the names of which do not have any reference to the chemical composition. The following are a few of the most important of these products, with their boiling points and uses:—

Name.	Boiling Point.	Principal Use in Arts.
Cymogene	0° C. (32° F.)	Used in ice machines.
Rhigolene	18.3° C. (65° F.)	Used to produce cold by evaporation and as an anæsthetic.
Petroleum Ether	40° to 70° C. (104° to 158° F.)	As a solvent and for making "air gas."
Gasolene	48.8° C. (120° F.)	For making "air gas."
C Naphtha	82.2° C. (180° F.)	As a solvent for fats and rubber, hence for cleaning cloths.
B Naphtha	104.4° C. (220° F.)	
A Naphtha	148.8° C. (300° F.)	So-called "safety-oil."
Benzine (deodorized)	120° to 150° C. (248° to 302° F.)	For varnishes and paints.
Kerosene, or Refined Petroleum	176° C. (349° F.)	For ordinary lamps.
Mineral Sperm Oil	218° C. (424° F.)	
Lubricating Oil	301° C. (574° F.)	Lubricating machinery.
Paraffine	Solid. Melts at 45° C. to 65° C. (113° F. to 149° F.)	For candles.

The vapors of all the lighter products when combined with air form explosive mixtures, and hence, laws exist in most countries prescribing the lowest temperature at which kerosene shall give an inflammable vapor, or at which it shall "flash." The law of the state of New York declares that oils used for illuminating purposes shall not give a vapor that will "flash" below 100° F., and shall not themselves ignite below a temperature of 300° F. Fossil resins, bitumen, and ozocerite (mineral wax) all belong to this group of hydrocarbons.

Benzine—Benzinum, U. S. P., is a purified distillate from American petroleum consisting of a mixture of hydrocarbons chiefly of the marsh gas series (C_5H_{12}, C_6H_{14}) and homologues. It is a colorless, transparent, mobile liquid, of aromatic odor.

It has a sp. gr. of 0.670 to 0.675 and boils at from 50° C. to 60° C. (122° F. to 140° F.). It is used principally as a solvent for fats, resins, alkaloids, and rubber. Owing to its solvent power for fats, it is used as a household article for cleaning fabrics.

Commercial benzine is usually heavier than the above liquid and has a higher boiling point.

Petrolatum Liquidum, U. S. P., is a colorless or yellowish, transparent, odorless, tasteless, oily liquid, giving off when heated a faint odor of petroleum. It consists chiefly of hydrocarbons of the marsh gas series, and is obtained from petroleum by distilling off the more volatile portions, and purifying that portion of the distillate having the proper consistence. Sp. gr. about 0.875 to 0.945 at 15° C. (59° F.). It is insoluble in water, but soluble in hot absolute alcohol, in ether, chloroform, benzine, carbon disulphide, turpentine and the fixed and volatile oils. **Albolene, benzoinol** and liquid vaseline are trade names for similar liquids.

Vaseline—Petrolatum Molle, U. S. P., and **Petrolatum Spissum,** U. S. P., are described as mixtures of hydrocarbons, chiefly of the marsh gas series, obtained by distilling off the lighter and more volatile portions from petroleum, and purifying the residue when it has the desired melting point. The first has a melting point of 40° C. to 45° C. (104° F. to 113° F), and the second of 45° C. to 51° C. (113° F. to 125° F.). They are fat-like masses having a white to deep yellow color, and more or less fluorescent.

The Olefines, or C_nH_{2n} **Series.**—The olefines differ from the paraffins in being unsaturated compounds. The first member of the series, ethene or ethylene (C_2H_4), combines directly with chlorine, forming a thick, oily fluid, from which the discoverers named it olefiant gas. The iodide and bromide may also be formed by direct union. The olefines combine with the hydracids, HCl, HBr, HI, and also with fuming H_2SO_4, and with HNO_3.

$$C_2H_4 + HCl = C_2H_5Cl.$$

Most olefines are soluble in alcohol and ether, but most are insoluble in water. They are soluble in strong H_2SO_4. Ethene is found in illuminating gas, the illuminating power of which depends largely upon its presence. It is a colorless gas of a peculiar, pungent odor, and may be separated from the other constituents by its solubility in H_2SO_4 with which it combines. It burns in the air with a bright luminous flame. Its sp. gr. is .9785; density 14. The higher members of this group are unimportant. The following are the chief members of the series:

Ethene (C_2H_4) gas.
Propene (C_3H_6) gas.
Butene (C_4H_8) gas.
Pentene (C_5H_{10}) boils at 35° C.
Hexene (C_6H_{12}) " " 70° C.
Heptene (C_7H_{14}) boils at 100° C.
Octene (C_8H_{16}) " " 125° C.
Nonene (C_9H_{18}) " " 153° C.
Decene ($C_{10}H_{20}$) " " 200° C.

Third Series. — Ethine, or **Acetylene** (C_2H_2). This series of hydrocarbons falls short of saturation by four monad atoms and can, therefore, act as bivalent and tetrivalent radicals. The first member of the series, ethine (C_2H_2), is the only hydrocarbon which can be formed by the direct union of its elements. It is produced when carbon is strongly heated in an atmosphere of hydrogen; that is, by passing a powerful electric current between carbon poles in a globe filled with hydrogen. It may be prepared in quantity by the reaction between calcium carbide and water:

$$CaC_2 + H_2O = CaO + C_2H_2.$$

One gram of CaC_2 is sufficient to yield 300 c.c. of the gas. Ethine, or acetylene, combines directly with either two or four atoms of chlorine, bromine, or iodine. Nascent hydrogen converts it into ethene, and oxidizing agents (potassium permanganate, etc.) into oxalic acid. Ethine is formed whenever benzene or coal gas is incompletely burned, and gives the disagreeable odor detected in a room when the lamp is turned low. It is found in coal gas, and possesses a high illuminating power. This hydrocarbon is remarkable in the fact that its hydrogen is easily displaced by metals; thus, by heating sodium with C_2H_2 we obtain C_2HNa (**mono-sodium acetylid**) and C_2Na_2 (**di-sodium acetylid**). When passed into a solution of silver nitrate it forms a white precipitate of **silver acetylid** ($C_2Ag_2H_2O$), an explosive compound.

Fourth Series.—*General Formula.* C_nH_{2n-4}. This series of hydrocarbons includes turpentine and a large number of other so-called essential, or volatile oils. To this series belong the **terpenes**, a class of hydrocarbons more or less resembling the turpentines in physical properties. Some of them show a close relationship to the aromatic hydrocarbons. The terpenes are isomers or polymers having the formula $(C_5H_8)_n$. These hydrocarbons are unsaturated, and those of the formula $C_{10}H_{16}$ may combine with either one or two molecules of the haloid hydracids, (HCl, HBr, HI), or two or four atoms of bromine, showing that their molecules contain either one or two double-linked carbon atoms.

Many of the terpenes form characteristic compounds with nitrous acid called nitrosites, $C_{10}H_{16}N_2O_3$, and also with nitrosyl chloride, NOCl, called nitroso chlorides. These compounds are crystalline. Some of these compounds form crystalline hydrates with water, especially in the presence of dilute nitric acid and alcohol, such as terpin hydrate. Some of them polymerize when heated under pressure or when shaken with strong H_2SO_4. Many of them are optically active, and all have an antiseptic action.

Turpentine, **Terebenthina**, U. S. P., **Pinene**, is an oleoresin extracted from several varieties of the conifera family, notably the pines. It is a yellow opaque tough mass, brittle when cold, and having a terebenthinate odor and taste. When turpentine is distilled, the terpenes volatilize, while resin or **colophony** remains behind. Oil of turpentine is a mobile, colorless liquid, with a sp. gr. of 0.855 to 0.870, and boils at 160° C. (320° F.). It is almost insoluble in water, but dissolves in alcohol, ether and glacial acetic acid. It dissolves sulphur, resin and phosphorus. It absorbs oxygen from the air and becomes oxidized, forming a resinous body. The absorbed oxygen is converted into ozone, and this explains its oxidizing, disinfectant, and antiseptic action. As the oxidation of turpentine takes place more rapidly when mixed with lead oxide, this oxide is often intermixed with the turpentine in paints, to increase the rapidity of drying. It attacks lead rapidly, but not tin.

A paper dipped in turpentine and introduced into a jar of chlorine gas inflames spontaneously, forming substitution products. Iodine and bromine have a similar action upon it. It unites directly with HCl, producing several hydrochlorates.

Sulphuric acid acts violently upon turpentine, and yields a number of isomeric and polymeric derivatives. After standing 24 hours, the mixture separates into two layers. The upper layer, when distilled at about 250° C. (482° F.), yields a mobile liquid, which, when purified by longer contact with H_2SO_4 and then with a solution of NaOH and redistilled, may be separated into **terebene** ($C_{10}H_{16}$), **colophene,** and several other polymers. These compounds are used in medicine.

Terebene —Terebenum, U. S. P., has a fine thyme-like odor, and is optically inactive. In density and other respects it much resembles turpentine. It is a liquid consisting chiefly of pinene, with small quantities of terpinene and dipentene. Terebene, when pure, is a colorless, or yellow oily liquid. It is readily soluble in ether, less so in alcohol, and almost insoluble in water. It has been used in medicine as an expectorant in doses of from 4 to 6 minims, and as a local remedy.

Terpin Hydrate.—On leaving turpentine in contact with the air for some time it gradually changes into terpin hydrate ($C_{10}H_{18}(OH)_2.(H_2O)$). This body is more easily obtained by agitating, for a day or two, a mixture of 8 parts of turpentine and 2 of nitric acid, previously diluted with alcohol. Terpin hydrate occurs as anhydrous rhombic crystals. It is easily soluble in alcohol (10 parts), slightly soluble in water (250 parts), and sparingly so in chloroform, carbon disulphide, and ether. It melts at 116° C., giving off water and being converted into anhydrous terpin ($C_{10}H_{18}(OH)_2$. It is a crystalline body, fusing at 103° C. and subliming at about 250° C. (480° F.),).

It rapidly absorbs water to form terpin hydrate, which behaves like a diatomic alcohol. It is dehydrated by P_2O_5 and converted into terebene and colophene. It is employed in medicine as an expectorant, in doses of from two to three grains. It may be given in as large as 20- to 30-grain doses.

Terpinol.—By boiling together terpin and water, acidulated with sulphuric acid, terpinol is obtained. It may be formed from turpentine by leaving it in contact with concentrated hydrochloric acid, or by passing HCl gas through a solution of terpin in alcohol and ether. By treating the resulting terebenthin dihydrochlorate with boiling water or a solution of KOH it decomposes with the formation of terpinol. Terpinol occurs as a colorless oily liquid, with an odor resembling rosamin or hyacinths, having a sp. gr. of .852. Terpinol is not a single body, but is said to be a mixture of *terpinene*, *terpinolene*, *dipentene*, all having the formula $C_{10}H_{16}$, and an alcohol called *terpineol*, $C_{10}H_{17}OH$.

Terpinol is soluble in alcohol and ether, but insoluble in water. It has been employed in medicine as an expectorant, in doses of from 10 to 15 minims (600 to 900 mgrs.).

Caoutchouc, or **India Rubber**, is the dried milky juice of several tropical trees of the *Hevea* species. The fresh juice is acid. It is a mixture of several hydrocarbons which are insoluble in alcohol and water, but soluble in ether, benzene, chloroform, carbon disulphide, and turpentine. When cold it is hard and tough, but on heating it becomes soft, elastic, and finally melts, and on cooling remains soft and viscid. It is much used in making elastics, water-proof fabrics, elastic tubing, etc., and is acted upon by but few reagents. The black color of the commercial article is due to smoke and partial decomposition.

Caoutchouc combines with sulphur. **Vulcanized** India rubber is obtained by mixing it intimately with sulphur, by the aid of carbon disulphide, to the extent of 2 or 3 per cent., and afterward heating. Common white rubber goods, as rubber tubing, etc., are also mixed with oxide of zinc and other impurities to a very large extent, in some cases but a few per cent. of rubber being used. When mixed with about half its weight of sulphur, a hard, horny mass called **vulcanite**, or **ebonite**, is produced, which is used in the manufacture of combs, cheap jewelry, etc. When heated, caoutchouc decomposes but does not volatilize.

Gutta-percha is the hardened, milky juice of *Isonandra gutta*, a tree growing in some parts of India. It resembles caoutchouc, but is harder and less elastic. In hot water it becomes quite soft, and can be moulded into any shape, which it retains on cooling. With solvents and high temperatures it behaves like caoutchouc.

Volatile or **Essential Oils.**—Volatile oils are those approximate principles to which, in the majority of cases, the odors of plants are due. They are extremely variable in composition, but many of them belong to the terpene series of hydrocarbons. The principal characteristics of these essential oils are their odors, variations in the rapidity of oxidation, and physical properties. They are soluble in alcohol, ether, benzene, petroleum, naphtha, chloroform, carbon disulphide, paraffin, other volatile oils, and in the fixed oils. They may be classified as follows:

1. Oils consisting chiefly of terpenes ($C_{10}H_{16}$) and their oxidized products; such as turpentine, oil of lemon, and the oils of bergamot, birch, chamomile, caraway hops, juniper, myrtle, nutmeg, orange, parsley, pepper, savin, thyme, tolu, and valerian.

2. Oils consisting chiefly of cedrenes ($C_{16}H_{26}$) and their oxidized products; such as the oils of cedar, cubebs, cloves, rosewood, calamus, cascarilla, and patchouli.

3. Oils consisting chiefly of aromatic aldehydes and allied bodies; such as the oil of almonds and the oil of cinnamon.

4. Oils consisting chiefly of ethereal salts or compound ethers; such as the oil of wintergreen or the oil of mustard.

Some of the more important oils of classes three and four are described in other places. These volatile oils, of which the hydrocarbons form the main constituent, probably originally consisted of terpenes or cedrenes only. As usually met with, they are generally mixtures of the unchanged hydrocarbons, or **oleoptenes**, with the solid, oxidized, camphorized bodies termed **stearoptenes.** We frequently, also, find more highly oxidized bodies called **resins.** On cooling the crude oil, the stearoptenes often crystallize out. On distilling the oils, the more volatile hydrocarbon first passes over, and may thus be separated from the oxidized solid portions. The more volatile portion of the distillate may be wholly freed from the oxygenized bodies by distilling with free sodium, and thus the pure hydrocarbon is obtained.

The volatile oils of plants are extracted:

1. By pressure, as the oils of laurel, lemon, orange, bergamot, etc.

2. By distillation with water, or with a current of steam passed over the matter to be extracted. This is the most common method.

3. By first fermenting the part of the plant to be extracted. This is applied more especially to certain seeds, as the mustard, bitter almond, etc. After the fermentation, the oil formed is separated by distilling with water.

4. By solution in the fixed oils devoid of odor, such as poppy oil, oil of ben, etc

The essential oils are usually liquid at ordinary temperatures, but deposit stearoptenes or camphors at low temperatures. They have, in most cases, highly characteristic odors, and a few have boiling points which are somewhat high. They volatilize rapidly at ordinary temperatures. The essential oils are usually colorless or yellow when freshly prepared, but darken on exposure to air and ultimately become sticky and resinous. Some oils have a well-marked blue color. Most of the essential oils are optically active, but their rotatory powers are variable and frequently change. The sp. gr. of essential oils ranges usually between .850 and .990. A few, however, have specific gravities outside these limits. The oxygenated and sulphuretted oils, as the oil of bitter almonds, wintergreen, mustard, etc., are heavier than water.

The essential oils are readily combustible. They are insoluble, or nearly so, in water, the water taking up, however, the characteristic smell and taste of the oils. They are freely soluble in alcohol, but are mostly precipitated on dilution with water. The separation is rarely, if ever, complete. The essential oils are miscible in all proportions in the fixed oils. Turpentine, petroleum naphtha, and carbon disulphide being insoluble in water, the essential oils may be separated from an aqueous liquid by agitation with these solvents.

The **analysis** of essential oils presents great difficulties. They are liable to adulteration with alcohol, chloroform, and turpentine.

Alcohol in essential oils may be detected by gradually adding dry $CaCl_2$, agitating, and warming the mixture in a water bath. If alcohol is present in larger proportions than mere traces, a heavy liquid layer will be formed at the bottom of the tube. Anilin red is insoluble in essential oils if pure and free from alcohol, but in the presence of a small proportion of alcohol, the addition of anilin red colors them a deep red.

Chloroform may be detected by dissolving the oil in alcohol, and warming the liquid with zinc and dilute sulphuric acid. Water is added, and the aqueous liquid is separated and tested for chlorides with $AgNO_3$ and HNO_3. The precipitation of AgCl proves the presence of chloroform in the oil.

A large number of volatile oils are employed in medicine either in a pure state or in the form of aqueous saturated solutions, called **medicated waters**. Solutions in alcohol, one in five, are termed **essences**; one in fifty are termed **spirits.**

THE CAMPHORS.

The camphors are oxidation products of essential oils of terpenes. Some of them, Japan camphor and carvol, $C_{10}H_{14}O$, are ketones, while most of them are alcohols. The most important camphors are the following:

Common Japan Camphor, $C_{10}H_{16}O$, is obtained in China and Japan by distilling the branches and leaves of *Laurus camphora* with water. It is a white, translucent, crystalline mass, having a powerful, peculiar, pungent odor and taste. It is readily purified by sublimation at 205° C. (401° F.). It melts at 175° C. (347°F.) and burns with a smoky flame. Camphor is very slightly soluble in water, but readily soluble in alcohol, ether, acetic acid, benzene, chloroform, carbon disulphide, fixed and essential oils. **Aqua Camphoræ** and **Tinctura Camphoræ** are official. Camphor enters into the composition of **Linimentum Camphoræ, Liniment, Saponis, Tinctura Opii Camphorata.**

Camphor forms a large number of decomposition products and derivatives under the action of reagents, but we shall notice but one of these.

Borneol, or **Borneo Camphor,** has the formula $C_{10}H_{17}OH$.

Camphor Monobromide — Camphora Monobromata (U. S. P.), $C_{10}H_{15}BrO$, is prepared by adding bromine to a solution of camphor in chloroform, by which camphor dibromide is obtained. This compound is unstable, and on standing, sets free hydromic acid and forms monobromated camphor, which crystallizes in colorless, prismatic needles or scales, permanent in the air, having a mild camphoraceous odor and taste, and a neutral reaction. Its solvents are essentially the same as those of camphor. It melts at 76° C. (168.8° F.), boils at 274° C. (525° F.), and is volatilized with partial decomposition. In medicine it is used as a sedative, cardiac stimulant, etc. Isomeric with borneol are linalool and geraniol.

Linalool, $C_{10}H_{17}OH$, is a monatomic alcohol found either free or as an ether in oil of lavender, bergamot, spike, coriander, and lanalol. It is a colorless, fragrant liquid of sp. gr. 0.878 and boiling at 197° C. (386.6° F.).

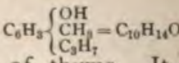
Geraniol, $C_{10}H_{17}OH$, is the chief constituent of Turkish geranium oil, and is found in oil of rose, oil citronella, oil of lavender, and oil of eucalyptus. It is a colorless liquid, with a fragrant, rose-like odor, boiling at 230° C. (446° F.).

Eucalyptol, $C_{12}H_{20}O$, is a colorless liquid, boiling at 175° C. (347° F.), and possessing an aromatic odor. It is contained in the leaves of the *Eucalyptus globulus,* a tree growing in Tasmania. On account of its supposed effect upon miasmatic atmospheres, it has been cultivated in southern Europe, the United States and northern Africa. By distilling it with phosphorus pentachloride, PCl_5, **eucalyptin,** $C_{12}H_{18}$ (by some $C_{10}H_{16}$), is obtained. Eucalyptol is slightly soluble in water, but soluble in alcohol. The oil has feeble antiseptic properties, and has been used in bronchitis cystitis, and in intermittent fever.

Citral ($C_{10}H_{16}O$) is a golden yellow liquid found in oil of lemon.

Citronellal ($C_{10}H_{18}O$) is a colorless oily liquid found in oil of citronella and oil of lemon.

Menthol,* or **Menthyl Alcohol,** $C_{10}H_{20}O$ (U. S. P.), is a white, solid, crystalline body occurring in oil of peppermint, and possessing a strong odor of this plant. It melts at 43° C. (109.4 F.), and boils at 212° C (413.6° F.). Menthol is soluble in alcohol and the essential oils.

Thymol—Methyl-propyl-phenol,  $C_6H_3\left\{\begin{array}{l}OH\\CH_3\\C_3H_7\end{array}\right. = C_{10}H_{14}O$. Thymol is a camphor or stearoptene of oil of thyme. It is also contained in the volatile oil of horse mint. It is extracted by agitating the oil with a solution of NaOH. The aqueous layer is separated and treated with a dilute acid, when the thymol separates as an oily layer. The better plan is to collect the crude oil and subject it to low temperature, when the thymol crystallizes out. It may be purified by recrystallization from alcohol. Thymol is a phenol, and resembles carbolic and cresylic acids in its general properties. It is a powerful antiseptic, being ten times more effective than carbolic acid. It acts as an expectorant on the mucous membranes, but it does not irritate the skin like carbolic acid. Thymol occurs in large colorless crystals, having an aromatic odor and a burning taste. It melts at 50° C., and boils at about 230° C. It is scarcely soluble in water, requiring about 1200 parts of cold or 900 parts of boiling water for solution. Alcohol dissolves its own weight of thymol, and the greater part separates again on dilution. A solution of four grains of thymol to a fluid ounce of alcohol is miscible with water in all proportions. It is sparingly soluble in glycerin, requiring 120 parts for solution. It is readily soluble in ether, chloroform, petroleum spirit, and oils. When triturated with camphor, a syrupy liquid is obtained which is readily miscible with vaseline or similar preparations. Thymol is soluble in strong acetic acid. A delicate test for thymol consists in dissolving a little of the sample in 1 c. c. of glacial acetic acid, and adding 5 or 6 drops of strong sulphuric, or 1 drop of nitric acid, when, if thymol be present, it first becomes green, and then on shaking, a fine blue color makes its appearance. Phenol gives a violent red color, but menthol, camphor, borneol, and salicylic acid, give no color when similarly treated.

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* Although really an alcohol, it is classed here with the camphors, owing to physical properties.

Cantharidin ($C_{10}H_{12}O_4$) is the active principle of cantharides, or Spanish fly, and of other vesicating insects. It has many of the properties of camphor. When pure it forms four-sided prisms, but frequently deposits in needles of micaceous appearance. It melts at about 200 C. (392° F.), and sublimes in white flakes, which strongly irritate the eyes, nose, and mouth, and condense in lustrous rectangular prisms. Cantharidin has feeble acid properties. It is insoluble in water, but dissolves in caustic alkalies to form cantharidates. Cantharidin may be crystallized from hot hydrochloric acid, but is soluble in strong sulphuric acid, being reprecipitated on dilution. Cantharidin dissolves readily in alcohol, ether, acetic ether, and chloroform. It is nearly insoluble in naphtha and carbon disulphide. It is extracted from acidulated solutions by agitation with chloroform. Cantharidin has well marked poisonous properties, and the beetles containing it have been administered with criminal intent. In toxicological inquiries the contents of the stomach and intestines should be carefully examined for the iridescent green wing-cases of the beetle. If the tincture has been taken, the only available test is the isolation of the cantharidin with chloroform, and the application of the residue to a sensitive part of the skin. The mixture of one part of cantharidin in 500 of lard produces very strong vesication, and .001 grm. of cantharidin dissolved in a drop of alcohol also produces marked vesication.

RESINS, OLEO-RESINS, GUMS, BALSAMS.

Many of the bodies of the turpentine and essential oil series above mentioned, when exposed to the air, undergo a process of oxidation or hardening, become viscid or solid, and exhibit an acid reaction.

Such bodies, when brittle and solid, are called **resins**; when composed of unoxidized oils mixed with resins, they are called **balsams**; when the resins exist in the juices of plants mixed with gum, sugar, etc., they are called **gum-resins**. Each one of these bodies is generally a mixture of several bodies, and, therefore, no definite chemical formula can be given. They are insoluble in water, but soluble in strong alcohol, turpentine and glycerin; many are soluble in ether and benzene (separation from gums); many are weak acids, whose alkaline salts form the **resin soaps** of the market. Many resins are used in medicine, in the manufacture of ,varnishes, sealing-wax, and salves. The resins are soluble in alcohol.

The resins soften when heated, but do not vaporize. The separation of resins from volatile oils and acids, is effected by **distillation** with water; from gums, by **fusion** and straining at 100° C. (212° F.), from each other, as well as from foreign substances, by properly selected **solvents.**

Under the name of resins the following substances are classed:

Amber, colophony (rosin), copal (anime), dammar, lac, Burgundy pitch, mastic and sandarac, which are used in the arts for making varnish, and for other uses.

The following are some of the resinous substances used in medicine: **Arnicin,** from arnica flowers; **castorin,** from castoreum; **cannabin,** from cannabis indica; **dragon's blood,** an exudation from the fruit of *Calamus draco;* **elemi,** a resin from Central America, an exudation from the *Amyris elemifera*; a resin found in ergot of rye; **guaiacum,** an exudation from the wood of the *Guaiacum officinale;* **jalap,** the resin of jalap root; **labdanum,** an exudation from the bark of several varieties of the *cistus*, grown in Greece; **podophyllin,** from the Mayapple root; **pyrethrum,** from pellitory root, and **rottlerin,** from the kamala, a shrub grown in East Indies.

Dammar is the exuded and hardened sap of the *Dammara orientalis*, a coniferous tree growing in the East Indies, Australia, and New Zealand. It is also used in the manufacture of varnish.

Lac is a resinous incrustation produced on the bark of the twigs of various tropical trees by the puncture of the "lac insect." This crude gum is called "stick lac" in commerce. **Shell-lac,** or shellac, is formed by melting, straining, and drying it in thin sheets.

In the preparation of shellac the coloring matter is separated, and is sold under the name of **lac dye.**

It is easily soluble in alcohol. Lac is used extensively in the manufacture of varnish, lacquers, sealing-wax, etc.

Mastic is an exudation from the bark of certain trees found in the island of Chios in the Mediterranean. It occurs in pale yellow, transparent, brittle tears, soluble in alcohol and turpentine, and is used for making varnish. It is official, and enters into Pilulæ Aloes et Masticheș.

Guaiacum is a brittle, pulverizable solid, of a reddish-brown color. The gum dissolves in alcohol. It readily undergoes oxidation, producing bright colors. A mixture of the official tincture and oil of turpentine is frequently employed as a reagent for detecting blood in urine, with which it strikes a blue color.

Only the most common resins can be described.

Common Resin—Rosin—Colophony—is the residue left by distilling the balsam or crude turpentine of the pine with water. Turpentine distils off and leaves a yellow or brown, brittle, shining mass, which when melted forms the commercial rosin. It usually has a sp. gr. of about 1.04 to 1 10. It is nearly tasteless, but leaves a characteristic nauseous after-taste. It is insoluble in water, but is soluble in alcohol, ether, chloroform, and in the fixed and volatile oils. It is soluble in caustic, and even carbonated alkalies, forming soaps soluble in water. Colophony is composed chiefly of several resin acids, the chief of which is abietic acid, $C_{44}H_{62}O_4$. Sylvic acid, $C_{20}H_{30}O_2$, exists in small quantities.

It may be detected in mixtures, by boiling 5 grms. of the mixture with 20 c.c. of pure nitric acid, diluting when cold with an equal volume of water, and adding ammonia. If resin be present a blood-red solution is produced. Rosin is used in the manufacture of varnishes, sealing-wax, lamp-black, the common yellow soaps, cerates, and plasters.

Copal, or Animé, is a yellow, hard, brittle, more or less transparent solid, found on the coast of Africa, and is dug out of the soil by the natives. It is a fossil resin of recent origin. It is very hard, and soluble with great difficulty in alcohol and essential oils. It makes the best resin varnishes.

Amber is also a **fossil resin**, found on the shores of the Baltic in Prussia. It is a very hard, tough and transparent or translucent yellow solid. It is used for making beads, mouthpieces of pipes, and for the manufacture of superior varnish.

The best known **oleo-resins** are the oleo-resins of aspidium, capsicum, cubeb, copaiba, lupulin, pepper, ginger, male fern, frankincense, Canada balsam, and Canada pitch. They are usually extracted from the plants with ethylic ether, using 150 parts of ether for 100 parts of the plant. (U. S. P. method.) The ether is then distilled off, and the oleo-resin kept in a well-stoppered bottle.

The principal **gum-resins** are aloes, ammoniacum, asafœtida, myrrh, scammony, gamboge, galbanum, olibanum, and euphorium. All but the last are official. They occur in commerce mostly as compact masses of a yellow or brown color, composed of tears glued together with a hardened, gummy mass.

They are usually brittle enough to be pulverized, and are soluble in alcohol or ether. When rubbed with water in a mortar, they form milk-white emulsions. The most of them are soluble in caustic alkalies.

The chief **balsams** are benzoin, Peru, storax, and tolu.

Gum benzoin, as it is frequently called, occurs as rectangular blocks, which consist of milk-white tears agglutinated by a brown resin. It has a pleasant, balsamic odor, and is soluble in alcohol, forming tincture of benzoin. It contains from 12 to 20 per cent. of benzoic acid, which can be sublimed from it by a gentle heat. It usually contains a small quantity of cinnamic acid and sometimes vanillin. It contains several resins.

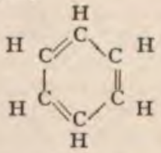
Balsam of Peru, storax, and tolu contain cinnamic ethers, resinous matter, and volatile oils. Benzoic acid is found in balsam of Peru and tolu.

They are all soluble in alcohol.

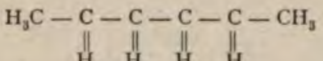
THE BENZENE OR AROMATIC HYDROCARBONS, OR CYCLO-HYDROCARBONS.

C_nH_{2n-6}.

The compounds of this series differ from all others thus far mentioned, in the structure of their molecules, in that the carbon atoms are arranged in the form of a closed chain, or cycle, at the angles of a regular hexagon,

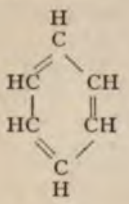


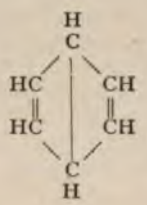
i. e., every carbon atom is the equivalent of every other, while in the other hydrocarbons, we have noticed a difference between the end ones and the others. The H atoms in benzene are all alike in behavior. We arrive at the idea that the C atoms are in a closed chain by the following facts. Benzene takes up two, four, or six atoms of H, Cl, or Br, according to the conditions of the experiment. Benzene thus becomes, in the first case, under the prolonged action of HI, hexa-hydro-benzene, C_6H_{12}, but the continued action of HI does not impart to it any more H atoms. If the carbon atoms were arranged in an open chain, it would become C_6H_{14}.

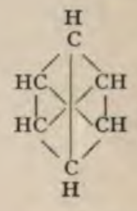


$$H_3C - \underset{H_2}{\underset{\|}{C}} - \underset{H_2}{\underset{\|}{C}} - \underset{H_2}{\underset{\|}{C}} - \underset{H_2}{\underset{\|}{C}} - CH_3$$

The **hexa-chloride** of benzene, ($C_6H_6Cl_6$), when once formed, refuses to take up more chlorine. The same is true of the hexa-bromide. In order to give an explanation of these facts, it is necessary to assume one of the following graphic formulæ as the proper arrangement of the C atoms in its molecule:—

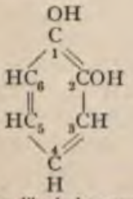




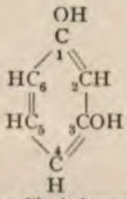


The first one of these three formulæ is the one suggested by Kekulé in 1866, and is the one now generally accepted.

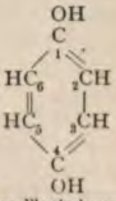
When di-derivatives from benzene are formed, we find three possible isomers. If, now, we examine the possible formulæ, we find the following possible groupings, in the case of the alcohols:—



Ortho-dihydrobenzene, or Pyrocatechin.

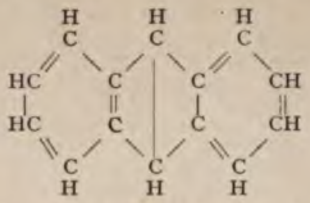


Meta-dihydrobenzene, or Resorcin.



Para-dihydrobenzene, or Hydroquinone.

Three benzene molecules thus condensed give a molecule of **anthracene** :—



Naphthalene, $C_{10}H_8$ **Naphthalinum,** U. S. P., is obtained from coal tar by distillation between 180° C. and 220° C. It comes over with heavy oils, but crystallizes from them in white, glistening, leafy crystals, of a peculiar, aromatic odor and burning taste; it melts at 79.2° C. (174.5° F.), is insoluble in water, but soluble in hot alcohol, ether, or benzene.

The principal interest of naphthalene to the physician is its value as an antiseptic dressing for wounds. For this purpose it must be thoroughly purified by recrystallization from alcohol, or distillation with steam. It is used internally as an antiseptic, and as a moth-destroyer under the name of **coal-tar camphor.** Naphthalene takes up hydrogen quite readily to form the dihydride $C_{10}H_8H_2$, the tetrahydride $C_{10}H_8H_4$, the hexahydride $C_{10}H_8H_6$ and the dekahydride $C_{10}H_8H_{10}$. It also forms a dichloride $C_{10}H_8.Cl_2$ and a tetrachloride $C_{10}H_8Cl_4$. This last compound when oxidized with nitric acid gives phthalic acid $C_6H_9(COOH)_2$.

It may be convenient here to consider two hydroxyl derivatives of naphthalene, because of their similarity in properties and uses.

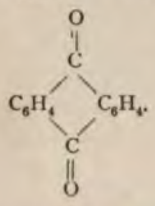
Naphthol, $C_{10}H_7OH$. — There are two well-known compounds of this formula, but the one generally used in surgery is **beta-naphthol.** There is also an **alpha-naphthol,** crystallizing in colorless, shining prisms, fusing at 94° C (201.2 F.) and boiling at 280° C. (536° F.). It is insoluble in water, but soluble in alcohol, ether, and benzene. Beta-naphthol is prepared on a large scale by fusing naphthalene-sulphonate of sodium ($C_{10}H_7SO_3Na$) with sodium hydroxide. Beta-naphthol is a solid, crystallizing in brilliant white plates, melting at 122° C. (251.6° F.) and distilling at 286° C. (546.8° F.), and possesses a sp. gr. of 1.217. It is very slightly soluble in warm water, very soluble in ether, alcohol, chloroform, benzene, olive oil, and vaseline. Beta-naphthol has been used as a local antiseptic. Alpha-naphthol forms a dinitro-derivative $C_{10}H_5(NO_2)_2OH$, which is used in dyeing. The sodium and calcium salts are used, and are known as Martin's yellow or naphthalene yellow. These have recently been largely replaced by the potassium sulphonate known as naphthol yellow, $C_{10}H_4(NO_2)_2\left\{\begin{matrix}SO_3K\\OK.\end{matrix}\right.$

β. **Naphthol-Salicylate—Betol,** $C_6H_4(OH)COOC_{10}H_7$ has been used for the same purposes as salol. It occurs as a white crystalline powder, almost insoluble in water.

Anthracene, $C_{14}H_{10}$, is a white, crystalline body obtained from coal tar, distilling above 360° C. (680° F.). Its constitution is shown by the graphic formula on page 325.

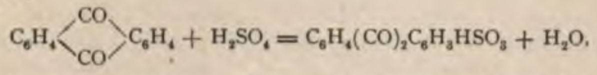
It is of great interest to the chemist, being the starting point in the manufacture of **alizarin,** $C_6H_4\begin{matrix}\diagup CO \diagdown\\ \diagdown CO \diagup\end{matrix}C_6H_2(OH)_2$ or artificial madder. Its solutions possess a beautiful blue fluorescence, a property observed in many of the heavier hydrocarbons derived from coal tar and petroleum; *i. e.*, their solutions are colorless or yellowish by transmitted light, but when viewed by reflected light, appear bluish. The phenomenon is well seen in solutions of quinine sulphate.

By oxidation anthracene gives **anthra-quinone.**



It occurs as yellow needle-like crystals, fusing at 273° C. (523° F.).

Alizarin is formed from anthra-quinone by the action, first, of fuming sulphuric acid, by which sulphonic acids are produced. These are then heated with potassium chlorate, and then with NaOH.



$$C_6H_4\begin{matrix}\diagup CO \diagdown\\ \diagdown CO \diagup\end{matrix}C_6H_4 + H_2SO_4 = C_6H_4(CO)_2C_6H_3HSO_3 + H_2O.$$

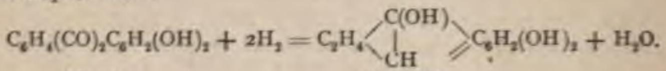
$$C_6H_4(CO)_2C_6H_3HSO_3 + NaOH = C_6H_4(CO)_2C_6H_3OH + NaHSO_3.$$

$$C_6H_4(CO)_2C_6H_3OH + O = C_6H_4(CO)_2C_6H_2(OH)_2.$$

The alizarin formed combines with the excess of NaOH present to form sodium alizarate. This is dissolved in water, and the alizarin precipitated with hydrochloric acid.

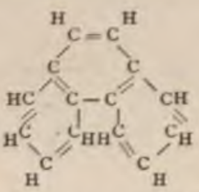
Alizarin is a fine red, crystalline powder, readily soluble in alcohol. It is a valuable dye-stuff, and has nearly displaced madder in the dyeing industry.

By the reduction of alizarin with nascent hydrogen **antharobin** is produced.



$$\underset{\text{Alizarin.}}{C_6H_4(CO)_2C_6H_2(OH)_2} + 2H_2 = \underset{\text{Antharobin.}}{C_2H_4\left\langle\begin{matrix}C(OH)\\ |\\ CH\end{matrix}\right\rangle C_6H_2(OH)_2} + H_2O.$$

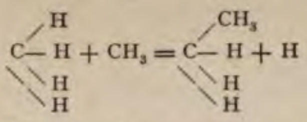
Antharobin has been used in medicine as a local application in skin diseases.

Phenanthren,  is an isomeride of anthracene, and is found with it in coal tar. It crystallizes in shining plates, and dissolves in alcohol more readily than anthracene. It melts at 100° C. (212° F.) and boils at 340° C. (644° F.). It is employed in making printer's ink.

DERIVED COMPOUNDS.

Addition and Substitution Products.—Addition products are formed by the direct combination of an unsaturated molecule with one or more radicals. They are readily formed from unsaturated hydrocarbons like the olefines or acetylenes. One molecule of the hydrocarbon always unites with two or four monivalent atoms or radicals, or with their equivalent in polyvalent radicals. It is especially the atoms of the chlorine group, or their hydracids, which are most easily added; but hydrogen, as well as other hydrocarbon radicals, may also be added.

Substitution products are formed by an exchange of one or more hydrogen atoms with simple or compound radicals. Indeed, we may regard all the complex organic bodies as made up in this way. Thus, Ethane, C_2H_6, may be regarded as a molecule of Methane, CH_4, in which one hydrogen atom has been displaced by the radical CH_3. Thus:—



Synthesis of Organic Compounds.—The principal interest of chemists in recent years, in the department of organic chemistry, is centred upon the synthesis of organic compounds. By these synthetical methods the chemist imitates, to a limited extent, the process of animal and vegetable organisms. The natural tendency of all organic compounds is to break up complex molecules and form simpler ones, while it is the aim of synthetical methods to reverse this process and build up complex molecules from simpler radicals, adding little by little until the structure is complete.

It is principally from synthetical relations that we can arrive at a knowledge of the structure of complex organic bodies. With these synthetic methods, chemists have achieved great success in the artificial production of alizarine (the coloring matter of madder), indigo, salicylic acid, and the great variety of anilin colors, which stand among the greatest achievements of modern science.

The Action of Reagents on Organic Compounds.—The reactions of organic compounds are so different from those of inorganic chemistry, that we introduce here a few of the principal reagents used and their behavior. Cl, Br, and I act upon unsaturated hydrocarbons by direct addition. With saturated bodies they substitute for H:

$$C_6H_6 + 3Cl_2 = C_6H_6Cl_6.$$
$$CH_4 + Cl_2 = CH_3Cl + HCl.$$

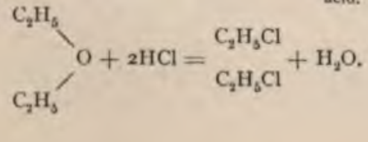
In the presence of water these act as oxidizing agents.

$$H_2O + Cl_2 = 2HCl + O.$$

HCl and HBr substitute Cl or Br for alcoholic hydroxyl.

$$\underset{\text{Alcohol.}}{C_2H_5OH} + HCl = \underset{\text{Ethyl chloride.}}{C_2H_5Cl} + H_2O.$$

$$\underset{\text{Lactic acid.}}{CH_3 - CHOH.COOH} + HBr = \underset{\text{Mono-brom-propionic acid.}}{CH_3 - CHBr - COOH} + H_2O.$$



With unsaturated hydrocarbons they combine directly.

$$C_2H_4 + HCl = C_2H_5Cl.$$

HI acts similarly to the above, but at higher temperatures it substitutes backwards, *i. e.*:

$$CH_2ICOOH + HI = CH_3COOH + I_2.$$

In compounds containing oxygen, which contain alcoholic hydroxyl, HI acts as a reducing agent removing the oxygen.

$$\underset{\text{Glycerin.}}{C_3H_5(OH)_3} + 5HI = \underset{\text{Iso-propyl iodide.}}{C_3H_5(H_2I)} + 3H_2O + 2I_2.$$

The free iodine acts as an oxidizing agent unless it be absorbed. This is usually done by adding some free phosphorus with which it forms PI_3, which, in the presence of water again forms HI.

H_2SO_4 acts upon the alcohols of the paraffin series by substituting HSO_4 for HO. It acts upon the hydrocarbons of the benzene series by substituting HSO_3 for H.

$$\underset{\text{Alcohol.}}{C_2H_5OH} + H_2SO_4 = \underset{\substack{\text{Ethyl sulphuric}\\\text{acid.}}}{C_2H_5HSO_4} + H_2O.$$

$$\underset{\text{Benzene.}}{C_6H_6} + H_2SO_4 = \underset{\substack{\text{Phenyl-sulphonic}\\\text{acid.}}}{C_6H_5HSO_3} + H_2O.$$

Under certain conditions we may have the following reactions:—

$$2C_2H_5OH + H_2SO_4 = \underset{\text{Ethyl sulphate.}}{(C_2H_5)_2(SO_4)} + 2H_2O.$$

$$2(C_6H_6) + H_2SO_4 = 2(C_6H_5)SO_2 + 2(H_2O).$$

HNO_3 forms nitric ethers with the alcohols of the paraffin series.

$$C_2H_5OH + HNO_3 = \underset{\text{Ethyl nitrate.}}{C_2H_5NO_3} + H_2O.$$

$$\underset{\text{Glycerin.}}{C_3H_5(HO)_3} + 3HNO_3 = \underset{\substack{\text{Nitro glycerin,}\\\text{glycerin trinitrate.}}}{C_3H_5(NO_3)_3} + 3H_2O.$$

With aromatic hydrocarbons it forms nitro-substitution products.

$$\underset{\text{Benzene.}}{C_6H_6} + HNO_3 = \underset{\text{Nitro-benzene.}}{C_6H_5NO_2} + H_2O.$$

H_2SO_4 and HNO_3, therefore, act alike on organic bodies.

NaOH and KOH in aqueous or alcoholic solution decompose (saponify) the compound ethers reproducing the corresponding alcohols.

$$\underset{\text{Acetic ether.}}{C_2H_5OC_2H_3O} + KOH = \underset{\text{Alcohol.}}{C_2H_5OH} + \underset{\substack{\text{Potassium}\\\text{acetate.}}}{KC_2H_3O_2}.$$

They substitute HO for Cl, Br, or I in haloid ethers.

$$\underset{\text{Ethyl chloride.}}{C_2H_5Cl} + KOH = \underset{\text{Alcohol.}}{C_2H_5OH} + KCl.$$

When fused with organic bodies, NaOH and KOH act as oxidizing agents, exchanging O for H, the H being set free.

$$C_2H_5OH + KOH = C_2H_3O_2K + 2H_2.$$

In such cases the tendency is always to form acids with which they combine. PCl_3 and PBr_3 and $POCl_3$ and $POBr_3$ substitute Cl or Br for OH in alcohols.

$$3C_2H_5OH + PCl_3 = 3C_2H_5Cl + PH_3O_3.$$
$$3C_2H_5OH + POBr_3 = 3C_2H_5Br + PH_3O_4.$$

PCl_5 and PBr_5 can substitute Cl or Br for O, or they may act like free Cl or Br.

$$\underset{\text{Aldehyde.}}{C_2H_4O} + PCl_5 = \underset{\text{Ethyl chloride.}}{C_2H_4Cl_2} + POCl_3.$$

P_2S_5 substitutes S for O in the hydroxyl of alcohols and acids.

$$5C_2H_5OH + P_2S_5 = 5C_2H_5SH + P_2O_5.$$

As an illustration of the synthesis of organic compounds we here introduce a few reactions, starting with the elements C and S. If we pass the vapor of sulphur over heated charcoal we get CS_2. The vapor of CS_2 mixed with H_2S, and passed over heated copper turnings forms methane, CH_4.

$$2Cu_2 + CS_2 + 2H_2S = 4CuS + CH_4.$$

When we pass a strong current of electricity between carbon poles in an atmosphere of H we obtain acetylene.

$$C_2 + H_2 = C_2H_2.$$

When acetylene is treated with nascent H, ethene is produced.

$$C_2H_2 + H_2 = C_2H_4.$$

C_2H_4 acted upon by HBr gives C_2H_5Br (ethyl bromide).

C_2H_5Br, when treated with nascent H, gives ethane, C_2H_6.

If instead of the bromide we form the iodide of ethyl, and treat this with zinc methyl, $Zn(CH_3)_2$, we obtain methyl-ethyl, or propane.

$$\underset{\text{Ethyl iodide.}}{2C_2H_5I} + \underset{\text{Zinc methyl.}}{Zn(CH_3)_2} = \underset{\text{Propane.}}{2C_2H_5CH_3} + ZnI_2.$$

By starting with propyl iodide, C_3H_7I, and treating this with KOH we obtain C_3H_6 (propene).

$$\underset{\text{Propyl iodide.}}{C_3H_7I} + KOH = \underset{\text{Propene.}}{C_3H_6} + KI + H_2O.$$

These reactions will show the methods of changing the hydrocarbons from one homologous series to another, and are introduced here merely as illustrations of the action of reagents.

Haloid Derivatives, or Haloid Ethers.—These substitution products are produced by the action of Cl or Br upon the paraffins, by the action of HCl, HBr, or HI upon the corresponding alcohols. These compounds may be considered as chlorides, bromides, or iodides of the alcohol radicals or alkyl radicals. When chlorine acts upon methane the hydrogen is gradually displaced by chlorine, forming **methyl chloride** (CH_3Cl), or **mono-chlor-methane, di-chlor-methane** (CH_2Cl_2), **tri-chlor-methane** ($CHCl_3$). **tetra-chlor-methane** (CCl_4).

Methyl chloride, mono-chlor-methane (CH_3Cl) is prepared on a large scale for use in freezing machines, by heating the hydrochloride of trimethylamin, to 260° C. (500° F.).

$$\underset{\text{Methylamin hydrochloride.}}{3N(CH_3)_3HCl} = \underset{\text{Methyl chloride.}}{2CH_3Cl} + \underset{\text{Trimethyl-amin.}}{2N(CH_3)_3} + \underset{\text{Methylamin.}}{NH_2CH_3} + HCl.$$

Trimethylamin is produced by distilling the refuse from the manufacture of beet sugar. This is neutralized with hydrochloric acid and then heated as above.

Methyl chloride is a colorless gas, slightly soluble in water and having a sweetish taste and odor. It is a liquid below —22° C. (—7.6° F.). It burns with a greenish flame. It is obtained by passing gaseous HCl into methyl alcohol, or by treating methyl alcohol with a mixture of H_2SO_4 and NaCl. These solutions have been used externally for the relief of neuralgia.

Methyl bromide and iodide are prepared by the action of phosphorus and bromine or iodine upon methyl alcohol. They are both liquids at ordinary temperatures.

Dichlor-methane, methylene chloride (CH_2Cl_2), is obtained, along with the other chlorine substitution products, by the action of Cl upon CH_4, or it may be obtained by the reduction of chloroform with nascent hydrogen. It is a colorless, oily liquid. boiling at 40° C. (104° F.). with an odor similar to that of chloroform. It is slightly soluble in water, is non-inflammable, and has been employed as an anæsthetic. It is not safer as an anæsthetic than chloroform.

Trichlor-Methane, Chloroform (U. S. P.), ($CHCl_3$).—Methyl chloride acted upon by chlorine produces a series of successive substitution products, one of which, **trichlor-methane,** is known under the name of **chloroform.** It was discovered in 1831 by Soubeiran and Liebig. On a manufacturing scale, it is usually prepared from common alcohol, as follows: In 24 parts of water, dissolve 6 parts of chloride of lime, strain into a retort, heat to 40° C. (104° F.), and add one part of strong alcohol. A reaction soon sets in, developing sufficient heat to distil over the $CHCl_3$. This distillate is purified by shaking it with water, and then pure H_2SO_4 (free from HNO_3), which chars any hydrocarbons or empyreumatic substances. It is then freed from acid by agitation with lime, and from water with dry calcium chloride.

Chloroform is a colorless, mobile liquid, possessing a peculiar, sweetish, ethereal odor and taste. It boils at 61° C. (142° F.); and has a sp. gr. of 1.49 at 15° C. (59° F.), and 1.473 at 25° C. (77° F.). It is not miscible with water, is uninflammable in the air, and dissolves fats, resins, caoutchouc, sulphur, phosphorus and iodine—the last with a violet-colored solution. Commercial chloroform is apt to be contaminated with alcohol, aldehyde and lower substitution products, and thus readily becomes useless on keeping. Purified chloroform (U. S. P.) is prepared from the above by mixing it with sulphuric acid, agitating, drawing off the chloroform, neutralizing with a solution of sodium carbonate, again drawing off, adding lime and alcohol, and finally distilling the chloroform in a water bath. **Chloral-chloroform** is the name sometimes applied to chloroform prepared from chloral by distilling with an alkali. It is so prepared because of its freedom from the impurities to which ordinary chloroform is subject. The best article for anæsthetic purposes is prepared in this way. Pure chloroform must not affect litmus, must not color a mixture of H_2SO_4, and chromic acids green, must not turn brown with H_2SO_4, or KOH, and must not suddenly evolve inflammable gases when heated with alcoholic solution of potassium hydroxide. It should not give a precipitate with silver nitrate, nor a yellow color with a solution of potassium iodide. No foreign odor should be observed on allowing a few drops to evaporate on the hand. Chloroform prevents putrefactive decomposition and fermentation.

Physiological Action.—When applied to the skin, chloroform acts as an irritant, and, if evaporation be retarded, as a vesicant. The vapor, when inhaled, produces anæsthesia. When used for this purpose, it should be quite pure, and some air should be admitted with the vapor when administered. The fatal accidents that have occurred in its use as an anæsthetic, are due to a paralysis of the heart, and, in some cases, at least, may be attributed to the exclusion of air from the lungs. It is safer for children, and with women in parturition, than with ordinary adults. It is eliminated slowly, and when injected hypodermically, the effect is slow in making its appearance and lasts for several hours. It should be administered with caution to persons who are the subjects of organic heart or renal diseases.

Impurities.—Chloroform is likely to contain as impurities alcohol, aldehyde or hydrochloric acid. Pure chloroform should leave no residue when a few drops are evaporated on a watch glass. When shaken with an equal volume of water, the latter when separated should not affect litmus paper; nor give a precipitate with $Hg_2(NO_3)_2$; nor liberate iodine from a solution of KI. A portion of it digested with a solution of KOH should not become dark (absence of aldehyde). If a dark color appears when 10 c. c. of chloroform are mixed with 5 c. c. of H_2SO_4, and allowed to remain in contact for 24 hours, it shows the presence of foreign substances of a dangerous character. If a few drops of chloroform be evaporated from a blotting paper on the palm of the hand, no foreign odor should be detected.

Detection of Chloroform.—A very delicate test for chloroform, even in the presence of alcohol, is to add some solution of NaOH in alcohol, and a little aniline, to the suspected liquid. Either immediately, or on gently warming the mixture, a strong odor of phenyl isocyanide is produced.

Second test.—When heated with Fehling's solution, chloroform very promptly precipitates cuprous oxide. Alcohol does not interfere with the test.

Third test.—When chloroform is added to a solution of beta-naphthol in strong KOH solution, and the liquid heated to about 50° C. (122° F.), a fine Prussian blue color is produced, changing gradually on exposure to the air to a green and finally to a brown. Chloral hydrate gives the same reaction. The boiling point of chloroform is a valuable indication of its purity. Pure chloroform boils at 60 8° C. (141.4° F.). The presence of one-half per cent. of alcohol reduces the boiling point to 59.8° C. (139.5° F.). A boiling point higher than 61° C. (141.8° F.) indicates the presence of amyl or butyl compounds.

Spiritus Chloroformi (U. S. P.) contains 6 per cent. by volume of chloroform, and 94 of alcohol.

Methyl Bromide (CH_3Br) or **mono-brom-methane**, and **dibrom-methane**, have little or no interest to the medical student.

Tri-brom-methane or **bromoform** ($CHBr_3$) closely resembles chloroform in properties. It boils at 150° C. (302° F.). It is not infrequently present in commercial bromine, even to the extent of 10 per cent. It is prepared by gradually adding bromine to a cold solution of KOH in methyl alcohol, until the liquid begins to be colored. It is rectified by treatment with $CaCl_2$ and redistillation. It is soluble in ether and alcohol, and but sparingly so in water.

Iodoform, Tri-iodo-methane, Iodoformum (U. S. P.) (CHI_3), is formed by the combined action of KOH and I upon ethyl alcohol. Its formation is a convenient test for alcohol. This compound is prepared by acting upon common alcohol, aldehyde and many other compounds with iodine, and potassium hydroxide or carbonate.

It crystallizes in yellow scales, which, under the microscope, resemble the beautiful forms of snow-flakes. It has a penetrating, saffron-like odor, melts at 120° C. (248° F.), and volatilizes slowly at ordinary temperatures. It is insoluble in water, but soluble in alcohol, ether, chloroform, bisulphide of carbon and fixed and volatile oils. It is neutral in reaction, and volatilizes completely on strongly heating.

Physiological Effects.—Iodoform is a stimulant and anæsthetic, when applied to wounds, and is much prized by many surgeons as an antiseptic dressing for wounds after operations. It prevents putrefactive decompositions and acts as a deodorizer; but its own odor is disagreeable to many persons.

Tests for Impurities.—Commercial iodoform, on agitation with water, should not yield a liquid precipitable by $BaCl_2$ or $AgNO_3$. (The absence of sulphides and chlorides.) It should be wholly soluble in boiling alcohol, and should leave no residue on ignition in the air. Picric acid has been used as an adulterant of iodoform. It may be detected by agitating a sample with a dilute solution of NaOH or Na_2CO_3, carefully neutralizing the filtrate with acetic acid, and adding potassium nitrate, when a yellow precipitate of potassium picrate will be thrown down.

Haloid Substitution Products derived from Ethylic Alcohol.—These are formed by replacing the hydroxyl group by one of the halogen elements, viz.: fluorine, chlorine, bromine, or iodine.

Ethyl Chloride, C_2H_5Cl, is prepared by passing gaseous HCl into a boiling solution of zinc chloride in twice its weight of alcohol. $C_2H_5OH + HCl = C_2H_5Cl + HOH$. The ethyl chloride distils over and is absorbed by alcohol. It is a colorless liquid of sp. gr. 0.92, boiling at 12.5° C. (54.0° F.)

Ethyl Bromide, C_2H_5Br, is prepared by the action of bromine and phosphorus on absolute alcohol. It is a colorless liquid, boiling at 39° C. (102° F.). It, as well as the chloride, has anæsthetic properties. The bromide has been employed for this purpose, but is not considered free from danger.

ALCOHOLS.

An alcohol may be regarded as a compound of hydroxyl and a hydrocarbon radical; or it may be regarded as the result of the substitution of OH for one or more H atoms in a hydrocarbon. In fact, nearly all hydrocarbons may be so changed by the action of hydrogen dioxide. It may also be regarded as constructed on the water type. It may then be regarded as a molecule of water, in which one of the hydrogen atoms has been replaced by a hydrocarbon radical.

$$HOH, HOCH_3\ HOC_6H_5.$$

Alcohols may be classified as mon-atomic, di-atomic, tri-atomic, etc., according to the number of hydroxyl groups in the molecule.

A **mon-atomic** alcohol is one containing but one OH group.

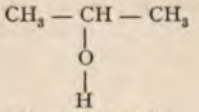
A **di-atomic** alcohol is one containing two OH groups.

A **tri-atomic** alcohol is one containing three OH groups.

Alcohols are also divided into primary, secondary, and tertiary.

A **primary** alcohol is one in which the hydroxyl is attached to a carbon atom which is united to but one other carbon atom—as $CH_3 — CH_2 — CH_2 — O — H$.

A **secondary alcohol** or **iso-alcohol** is one in which the hydroxyl group is linked to a carbon atom which is joined to two other carbon atoms, *i. e.*, the OH forms a side chain; as, for example,



$$\begin{array}{c}CH_3 — CH — CH_3\\ |\\ O\\ |\\ H\end{array}$$

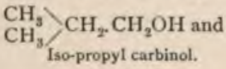
Iso-propyl alcohol.

Or, it is an alcohol formed from isomeric hydrocarbons. Thus from butane we may have two isomeric alcohols, according to the following formulæ:

$CH_3.CH_2.CH_2.CH_2OH$ and $CH_3.CH_2.CHOH.CH_3$.

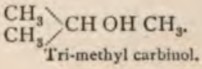
Normal Butyl Alcohol. Iso-butyl Alcohol.

From isobutane we also have two isomeric alcohols, the one primary and the other secondary:



$$\begin{matrix}CH_3\\CH_3\end{matrix}\!>\!CH_2.CH_2OH$$

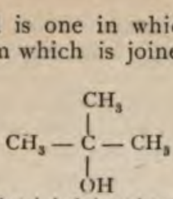
Iso-propyl carbinol.



$$\begin{matrix}CH_3\\CH_3\end{matrix}\!>\!CH\ OH\ CH_3.$$

Tri-methyl carbinol.

A tertiary alcohol is one in which the hydroxyl group is linked to a carbon atom which is joined to three other carbon atoms: for example,



$$CH_3-\overset{\overset{\large CH_3}{|}}{\underset{\underset{\large OH}{|}}{C}}-CH_3$$

Tertiary butyl alcohol or tri-methyl carbinol.

Secondary and tertiary alcohols are often called *carbinols*, and the groups or radicals united to the carbon atom holding the hydroxyl are given their special names. (See Amyl Alcohols, p. 351.)

Monatomic alcohols.—Having given a brief definition of the several groups of alcohols, we shall now proceed to notice briefly those members which may be considered of most importance to the student of medicine or pharmacy. We shall omit many of the compounds which are of chemical interest only.

TABLE OF MONATOMIC ALCOHOLS OF THE FIRST SERIES, WITH CORRESPONDING ACIDS.

ALCOHOLS.	Formula.	Boiling Point.	FATTY ACIDS.	Formula, +	Boiling Point.
Methyl Alcohol (Wood Spirit), ...	CH_3-O-H	66° C.	Formic Acid,	$HCHO_2$ +	100° C.
Ethyl Alcohol (Spirit of Wine), ...	C_2H_5-O-H	78.4°C.	Acetic Acid,	$HC_2H_3O_2$	118° C.
Propyl Alcohol, ...	C_3H_7-O-H	97° C.	Propionic Acid,	$HC_3H_5O_2$	141° C.
Butyl "	C_4H_9-O-H	116° C.	Butyric Acid,	$HC_4H_7O_2$	163° C.
Amyl, or Pentyl Alcohol, . .	$C_5H_{11}-O-H$	137° C.	Valerianic, or Pentylic Acid,	$HC_5H_9O_2$	185° C.
Hexyl Alcohol, ...	$C_6H_{13}-O-H$	157° C.	Caproic, or Hexylic Acid,	$HC_6H_{11}O_2$	205° C.
Heptyl "	$C_7H_{15}-O-H$	176° C.	Œnanthic, or Heptylic Acid,	$HC_7H_{13}O_2$	224° C.
Octyl "	$C_8H_{17}-O-H$	195° C. *Melting point.*	Caprylic, or Octylic Acid,	$HC_8H_{15}O_2$	233° C. *Melting point.*
Cetyl Alcohol, ...	$C_{16}H_{33}-O-H$	50° C.	Palmitic Acid,	$HC_{16}H_{31}O_2$	62° C.
			Stearic Acid,	$HC_{18}H_{35}O_2$	69.2° C.
Ceryl "	$C_{27}H_{55}-O-H$	79° C.	Cerotic Acid,	$HC_{27}H_{53}O_2$	78° C.
Melissyl "	$C_{30}H_{61}-O-H$	85° C.	Melyssic Acid,	$HC_{30}H_{59}O_2$	88° C.

METHYL ALCOHOL (Wood Spirit).

CH_3-O-H. Boils at 66° C. (150.8° F.).

Methyl Alcohol occurs among the products of the destructive distillation of wood, forming about one per cent. of the distillate. The alcohol is separated from the other products by careful fractional distillation. It is then redistilled after adding lime. This is then treated with dry calcium chloride, with which the alcohol combines to form a solid, crystalline body, from which other impurities may easily be separated; the alcohol is recovered from this solid by distilling with water. The water is finally removed by treating with quicklime and distilling at a low temperature. Oil of wintergreen consists chiefly of the methyl ether of salicylic acid. On distilling this oil with potassium hydroxide pure methyl alcohol is obtained.

Methyl alcohol is a transparent, colorless, mobile liquid, having a spiritous odor and a sp. gr. of 0.8142. It burns with a bluish flame. It is miscible with water in all proportions. By oxidation it yields formic acid.

$$CH_3OH + O_2 = CHO_2H + H_2O.$$

With acids it produces ethers. With acetic acid it gives methyl acetic ether, or methyl acetate, $CH_3—O—C_2H_3O$. With hydrochloric acid it gives methyl chloride, CH_3Cl. Many other ethers and substitution products are known. The **physiological action** of methyl alcohol is similar to that of common ethyl alcohol, but more transient. **Methylated spirit** is a mixture of 90 parts of common alcohol and 10 parts of methyl alcohol.

Ethyl Alcohol, Common Alcohol, C_2H_5OH.—It is prepared from saccharine liquids by the growth of a microscopic plant called yeast, or ferment. The process is called fermentation. Cane sugar, starch and cellulose can be fermented only after conversion into glucose or levulose, which can be accomplished slowly by the yeast itself.

$$C_{12}H_{22}O_{11} + H_2O = \underset{\text{Glucose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}.$$

$$C_6H_{12}O_6 + \text{yeast} = 2C_2H_6O + 2CO_2.$$

This reaction accounts for only 94 to 96 per cent. of the sugar employed, the remaining part being transferred into other products, such as succinic acid, glycerin, "fusel oil," etc. The yeast plant, under whose influence this change takes place, is known as Torula, or *Mycoderma cerevisiæ*. The sugar to be fermented may be from the juices of fruits or sugar cane, or it may be previously prepared from the starch of the cereals by the aid of malt or sulphuric acid. The secondary or side products in the fermentation vary somewhat with sugar from these various sources, and thus give rise to the different flavors of the fermented liquors. The alcohol may be separated from the water and other products after the fermentation by careful fractional distillation. If it be desired to prepare an alcohol containing more than 90 per cent., some substance must be added which will combine with and hold back the water, as quicklime, anhydrous copper sulphate, potassium carbonate, or barium hydroxide, after which it is again distilled.

Absolute Alcohol—Alcohol Absolutum (U. S. P.)—is a colorless, limpid liquid of an agreeable odor and burning taste. It attracts water, and mixes slowly with this liquid in all proportions, with the production of heat and contraction in volume. It boils at 78.4° C. (173° F.), and has never been solidified. It is neutral to test paper, and burns readily with a non-luminous flame. It dissolves resins, essential oils, alkaline hydroxides, calcium chloride, and a large number of organic bodies. Oxidizing agents convert it into aldehyde, and, finally, into acetic acid. Nitric acid (fuming) decomposes it very rapidly, giving a number of acids and ethers. If 90 per cent. of alcohol is added to a solution of mercury or silver in nitric acid, a rapid ebullition takes place, with a crystalline deposit of **fulminate of silver** or **mercury**, which explodes, when dry, by percussion, and is used in filling percussion caps. The formulæ are $C_2N_2O_2Ag_2$ and $C_2N_2O_2Hg$. The alkaline metals attack alcohol, and give ethylates of the metals.

$$2C_2H_5OH + K_2 = 2C_2H_5OK + H_2.$$

When distilled with sulphuric acid and a salt of an organic acid, it forms compound ethers.

Physiological Action.—Alcohol is, when concentrated, a poison. Even when taken in large doses well diluted, it has frequently caused death, probably by paralysis of the muscles of respiration or of the heart. In full doses it causes a feeling of warmth in the stomach, followed by congestion of this organ. After absorption, there is at first a feeling of exhilaration with exalted animal functions, quickened pulse and increased circulation, with dilatation of the superficial blood-vessels. This is often accompanied and always followed by incoherence of ideas and muscular actions, and finally a general weakness of all the voluntary actions. The temperature is lowered, both in health and in most diseased conditions The prolonged use of alcoholic beverages is characterized by general degenerative changes, either fatty or fibroid. There are no conclusive arguments to prove the benefit to be derived from the use of alcohol in health, but in certain diseased conditions it is of undoubted value.

Commercial Forms.—Commercial alcohol varies in strength from 85 to 95 per cent. **Alcohol Deodòratum** (U. S. P.) contains about 92.5 per cent. by weight, and 95.1 per cent. by volume, of ethyl alcohol. It is purer and stronger than the ordinary alcohol, which contains about 91 per cent. by weight, or 94 per cent. by volume, of alcohol, and about 9 per cent. by weight of water.

Deodorized alcohol should have a sp. gr. of about 0.816 at 15° C. (59° F.), and mixed with an equal volume of water and one-fifth volume of glycerin, and the mixture allowed to evaporate spontaneously from clean blotting paper should leave no foreign odor. It should not turn brown upon adding to it concentrated sulphuric acid.

Alcohol Dilutum contains 41 per cent. by weight, or 48.6 per cent. by volume.

Proof Spirit contains 49 per cent. C_2H_6O, so called because it is the weakest alcohol that will fire gunpowder.

Tinctures are solutions of medicinal non-volatile, or only partially volatile substances in liquids other than glycerin or water. Solutions of volatile substances in water are known as **medicated waters,** and similar solutions in alcohol as **spirits.** The liquids employed in the preparation of tinctures are alcohol of different strengths, spirit of ether, spirit of nitrous ether, mixtures of water, alcohol and glycerin, and aromatic spirit of ammonia or ammoniated alcohol. According to the liquid employed, tinctures are known as ammoniated, ethereal, or alcoholic. The greatest number of tinctures are made with alcohol. Most tinctures of the U. S. P. are prepared with diluted alcohol; those of the B. P with proof spirit. The U. S. P. official tinctures, of which there are 72, are made in three ways: (1) By percolation. (2) By maceration. (3) By solution or dilution.

Preparation of Tinctures.—Tinctures of resins, oleo-resins, balsams, and most of the gum resins are best prepared by maceration. All other drugs are conveniently extracted by percolation. This plan has been gènerally adopted by the U. S. P., where practicable. The B. P. directs first to macerate the drug for 48 hours and then to percolate. The Ger. P. directs to prepare all tinctures by maceration or digestion.

Detection and Estimation of Alcohol.—Alcohol may be detected in quantities of one per cent. or more in any fluid, by shaking the sample for a few minutes with a small quantity of powdered guaiacum taken from the center of a lump. Filter the liquid and add a few drops of diluted hydrocyanic acid, and a drop of a weak solution of $CuSO_4$. If alcohol be present, a blue color is produced, which can best be seen by holding the tube over white paper.

Second test: A very delicate test for alcohol depends on the fact that alcohol, under the influence of iodine and an alkali, yields iodoform, CHI_3. To 10 c. c. of the liquid add 5 drops of a 10 per cent. solution of NaOH, and warm to about 50° C. (122° F.). A saturated solution of iodine in a solution of KI is next added, drop by drop, until the liquid becomes slightly yellow. If alcohol be present, iodoform is gradually deposited in yellow crystals, which may be examined with a lens.

Third test: A solution of one part of molybdic acid in ten of strong H_2SO_4, when warmed with the suspected solution, immediately gives a blue color in the presence of alcohol, ether, or aldehyde. It will detect 0.1 per cent.

Alcohol is estimated quantitatively in mixtures with water, by means of its sp. gr. and reference to an alcoholic table prepared for the purpose. In tinctures, wine, beer, or other beverages, 100 c. c. of the sample is put into a retort and distilled until about one-half distils over. The distillate is collected and pure water added to make the volume up to that of the beverage taken. It remains then to take the sp. gr. of this solution, and refer to the table to determine the per cent. of alcohol. The sp. gr. in these cases must be taken with extreme care, with the sp. gr. bottle.

Alcoholic Beverages are usually of three classes, viz., distilled, fermented, and malt liquors. To the first class belong **spirits** distilled from fermented liquors—**brandy** from wine, **whiskey** from a mash of corn or rye, **rum** from molasses, **gin** from corn spirit mixed with juniper berries.

To the second class belong the various wines. To the third class belongs **beer**, prepared from malted barley and hops. **Ale, Porter,** and **stout** differ from beer only in the selection and proportion of the malt, hops, and flavoring materials.

We introduce here some results of the analyses of various distilled liquors, as found in the American market, for the purpose of comparison as to the ordinary strength of alcohol (N. Y. State Board of Health Report, 1882):—

		Brandy.	Whiskey.	Rum.
Specific Gravity,		0.9297 to 0.9615	0.9018 to 0.9646	0.9126 to 0.9684
		Per cent.	Per cent.	Per cent.
Alcohol	By Volume,	30.80 to 50.40	28.90 to 60.30	26.40 to 50.30
	By Weight,	25.39 to 42.96	23.75 to 52.58	21.66 to 42.87

It seems, therefore, that there is a great variation in the strength of these liquors as ordinarily sold; and while they are supposed to contain from 40 to 50 per cent. of alcohol by volume, in reality they usually contain from 35 to 45 per cent. It is, therefore, a very uncertain way of prescribing alcohol, to prescribe any one of these beverages. A much more certain method is to prescribe alcohol of known strength, flavored with ethereal essences, and softened with glycerin or syrup.

Wines contain from 6 to 25 per cent. of alcohol.

Port Wine,	16.62 to 23.2	per cent.
Sherry "	16.00 to 25.0	"
Bordeaux, Red,	6.85 to 13.0	"
" White,	11.00 to 18.0	"
Champagne,	5.80 to 13.0	"

COMPOSITION OF FORTIFIED WINES. (DUPRE.)

	SHERRY.	MADEIRA.	MARSALA.	PORT.
Sp. gr.,	.9979	.9939	.9966	.9974
Alcohol,	17.20	17.75	16.71	17.53
Extract,	5.38	4.35	4.98	5.39
Glucose,	2.97	2.08	3.24	2.28
Mineral matters,	0.55	0.39	0.22	0.26
Acidity (as tartaric acid),	0.52	0.54	0.33	0.49
Phosphoric acid,	0.025	0.042	0.018	0.033

The following table is taken from Fresenius and Borgmann, and shows the average composition of certain pure wines in grams per 100 c. c.:—

	RED MAIN.	WHITE MAIN.	HOCKS.	WHITE FRENCH.	RED FRENCH.	MOSELLE.
Alcohol—						
Maximum,	9.51	10.15	10.39	9.84	9.32	8.72
Minimum,	9.49	8.90	6.42	9.05	7.99	7.04
Average,	9.50	9.52	8.77	9.44	8.56	8.08
Extract,	3.00	2.43	2.32	2.54	2.44	2.11
Mineral matters,	0.32	0.19	0.22	0.26	0.25	0.18
Acidity,	0.58	0.69	0.62	0.62	0.54	0.79
Glycerin,	1.19	1.10	0.92	0.94	0.86	0.73
Sulphuric acid (SO_3),	0.076	0.044	0.047	0.017	0.013	0.012
Phosphoric acid (P_2O_5),	0.065	0.039	0.040	0.034	0.027	0.047

Beers and porters contain from 1 to 10 per cent.; average about 4 to 5 per cent. by volume. The average of extractive matters (dextrin, cellulose, sugar, lupulin, and hop resin) is 4 to 15 in ale, 4 to 9 in porter, and about 5 per cent. in beer. All alcoholic beverages are subject to gross adulterations. Artificial beverages are frequently sold in all markets.

The following table illustrates the composition of the following malt liquors (Allen):—

	SP. GR.	ALCOHOL.	SOLID MATTER OR EXTRACT.	FREE ACID.	ASH.
Pilsen Lager, ...	1,013	3.55	5.15	. . .	.20
Hanoverian Lager (average of 20 samples), ...	1.017	4.01	6.34	. . .	.24
American Lager (average of 19 samples), ...	1.016.2	2.78	~~6.05~~	~~0.12~~	.30
Bass's Pale Ale, ...	1.013.8	6.25	6.98	0.14	. . .
Alsop's Pale Ale, ...	1.014.4	6.37	4.44	0.24	. . .
Guiness's Stout, ...	. . . . .	6.66	7.24	0.20	. . .
" "	1.124.4	5.05	5.48	0.23	. . .
Dublin "	. . . . .	5.50	8.71	0.18	. . .
Munich Lager	1.021	4.75	7.08	0.15	. . .

Propyl alcohol, or **ethyl carbinol** (C_3H_7OH), is found in the latter portions of the distillate in rectifying crude alcohol. Its sp. gr is 0.82. It boils at 97.5° C. (207.5° F.). It may be separated from its mixture with water by saturating it with $CaCl_2$, which absorbs the water and allows the alcohol to separate as a layer. When oxidized, it yields **propyl aldehyde** (C_3H_6OH) and **propylic acid** (C_2H_5COOH).

Butyl Alcohol (C_4H_9OH).—There are four butyl alcohols known. The butyl alcohol of fermentation is formed during the alcoholic fermentation of sugars. It may be obtained by repeated fractional distillation of the heavier portions that come over at the end of the distillation of the mash. It is a colorless liquid, boiling at 116° C. (240.8° F.). It is more poisonous than ethyl or methyl alcohol.

Amyl Alcohol, Fusel Oil,* Potato Spirit, Propyl Carbinol ($C_5H_{11}OH$).—Of the eight possible theoretical amylic alcohols, seven are known:—

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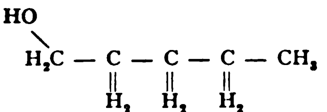
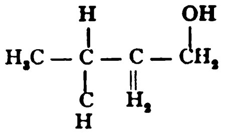
* Fusel oil, properly speaking, is a mixture of several alcohols, of which amyl alcohol is one.



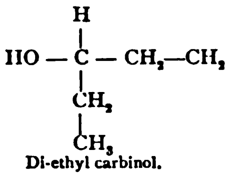
$$\mathrm{HO{-}H_2C{-}\underset{H_2}{C}{-}\underset{H_2}{C}{-}\underset{H_2}{C}{-}CH_3}$$

Normal amyl alcohol or primary amylic alcohol.



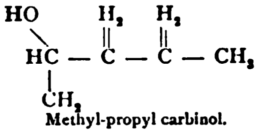
$$\mathrm{H_3C{-}\overset{H}{\underset{\underset{H}{C}}{C}}{-}\underset{H_2}{C}{-}\overset{OH}{CH_2}}$$

Secondary amylic alcohol, iso-butyl carbinol, or iso-amylic alcohol.



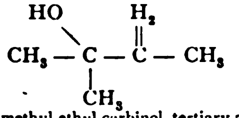
$$\mathrm{HO{-}\overset{H}{\underset{\underset{CH_3}{CH_2}}{C}}{-}CH_2{-}CH_3}$$

Di-ethyl carbinol.



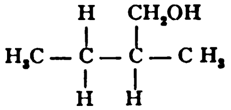
$$\mathrm{HO{-}\underset{CH_3}{HC}{-}\underset{}{\overset{H_2}{C}}{-}\overset{H_2}{C}{-}CH_3}$$

Methyl-propyl carbinol.



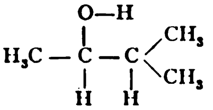
$$\mathrm{CH_3{-}\overset{HO}{\underset{CH_3}{C}}{-}\overset{H_2}{C}{-}CH_3}$$

Di-methyl-ethyl carbinol, tertiary amylic alcohol, or amylene hydrate.



$$\mathrm{H_3C{-}\overset{H}{\underset{H}{C}}{-}\overset{CH_2OH}{\underset{H}{C}}{-}CH_3}$$

Secondary isobutyl carbinol.



$$\mathrm{H_3C{-}\overset{O-H}{\underset{H}{C}}{-}\underset{H}{C}\langle{}^{CH_3}_{CH_3}}$$

Methyl-isopropyl carbinol.

Of these compounds the only ones of interest are iso-amyl alcohol and amylene hydrate.

Amyl alcohol (Iso-amylic alcohol) ($C_5H_{11}OH$) is formed in small quantities at the same time with ethyl alcohol, during the fermentation of barley, corn, and especially potato mash. It is prepared from the residue left in the still after the common alcohol has been distilled off. The product coming over at 132° C. (269° F.) is that collected.

It is a colorless oily liquid, possessing a peculiar, irritating odor which excites coughing, and a burning taste. It is not miscible with water, but mixes in all proportions with alcohol and ether. It is a good solvent of certain alkaloids. Taken internally, both in the form of vapor and when taken by the stomach, it acts as a poison, producing dizziness, headache, and intoxication. Much of the unwholesomeness of imperfectly rectified spirituous liquors arises from their contamination with fusel oil.

The principal uses of fusel oil are in the preparation of varnish, and as a source of amyl ethers, which are used extensively to prepare artificial flavoring extracts. Thus, the acetate has the odor of pears, and is used by confectioners under the name of "**pear oil,**" while the valerianate is used to give the flavor of apples, and is called "**apple oil.**"

Amylene Hydrate, or **Di-methyl-ethyl-carbinol,** $CH_3—CH_2—COH=(CH_3)_2$.—When amyl alcohol is heated with $ZnCl_2$, amylene, C_5H_{10}, is formed; this combines with hydriodic acid to form amylene iodide. This iodide when treated with Ag_2O gives tertiary amylic alcohol or amylene hydrate. This is a colorless liquid, boiling at 108° C. (226.4° F.), with a peculiar odor resembling menthol. It is soluble in eight parts of water and freely soluble in alcohol. It has been employed, in doses of 20 to 25 grains as a hypnotic.

Among the higher monatomic alcohols the following are of interest:—

Cetyl Alcohol, $C_{16}H_{33}OH$, formerly termed **Ethal,** is obtained by saponifying spermaceti (Cetaceum, U. S. P.), which consists of palmitate of cetyl. Spermaceti is a solid crystallized fat accompanying sperm oil, in the head of the sperm whale.

Ceryl Alcohol, $C_{27}H_{55}OH$, is obtained in the same manner from Chinese wax.

Melissyl Alcohol, $C_{30}H_{61}OH$, is obtained from that portion of beeswax soluble in alcohol, which is composed of melissyl palmitate. Yellow wax (cera flava, U. S. P.) and white wax, which is bleached by exposure to moisture, air, and sunlight, are prepared from the honey-comb. Beeswax contains, besides melissic palmitate, cerotic acid and cerolein. The adulterants found in wax are paraffin and ceresin. Both paraffin and ceresin reduce the melting point of wax, which should not be lower than 63.3° C. (146° F.). Pure wax will yield not more than 3 per cent. to cold alcohol, whereas resin, if present, would be extracted by the alcohol. Both paraffin and ceresin are insoluble in alcohol.

Diatomic Alcohols (glycols) are of little interest to the physician or pharmacist. They may be regarded as being derived from two molecules of water, in which one atom of H from each molecule has been displaced by a diatomic radical.

Glycol ($C_2H_4(OH)_2$), or **Ethylene Alcohol,** is a colorless, transparent, almost colorless liquid, less mobile than alcohol, having a sweetish taste, and boiling at 197° C. (386.6° F.). It dissolves in water and alcohol in all proportions. It is prepared by decomposing ethylene dibromide with potassium carbonate.

$$C_2H_4Br_2 + K_2CO_3 + H_2O = C_2H_4(OH)_2 + 2KBr + CO_2.$$

It has no practical applications in medicine.

TRIATOMIC ALCOHOLS, OR GLYCERINS.

Ordinary Glycerin—Glycerol, $C_3H_5\left\{\begin{matrix}OH\\OH\\OH\end{matrix}\right.$, was discovered by Scheele in 1779, and was called by him **the sweet principle of oils.** It is prepared on a large scale from the neutral fats, as a side product in the manufacture of soap and candles. These fatty bodies are composed of fatty acids in combination with glyceryl (C_3H_5), the radical of glycerin; *i. e.*, they are compound ethers of the fatty acids and glyceryl. On treating these ethers with alkalies, a salt of the alkali with the acid is formed, termed a soap; the glycerin is set free by the reaction and remains dissolved in the water present. This process of decomposing a compound ether into an alcohol and acid, or salt of the acid, is called **saponification.** Neutral fats can also be saponified by treating them with superheated steam, which is the process now usually employed in candle factories. The glycerin is freed from the water by evaporation, and finally, by distillation with the aid of superheated steam. Glycerin is also formed during alcoholic fermentation, and is found in wines, etc. It is a colorless, syrupy liquid, possessing a sweetish taste and no odor. Its density is 1.28 at 15.5° C. (60° F.). The official **glycerinum** has a density of 1.25. It is soluble in all proportions in water and alcohol, but not in ether. It is hygroscopic, and absorbs water readily until it has absorbed twice its own volume. Its range of solubility is large, as will be seen by the table in the appendix. When heated in air, it boils at 290° C. (554° F.), and distils with partial decomposition. At low temperatures, it forms, under certain circumstances, a crystalline mass. When heated in the air to a high temperature, it takes fire and burns, leaving no residue. Boric acid imparts a green color to its flame, or to a flame directed upon a platinum wire moistened with it. This is one of the most convenient tests for boric acid. Chemically, glycerin is, as above stated, a triatomic alcohol; *i. e.*, it contains three hydroxyl groups. When oxidized, it yields glyceric acid, $C_3H_3\left\{\begin{matrix}O.OH\\OH\\OH\end{matrix}\right.$. It is capable in certain circumstances of undergoing fermentation with yeast, producing ethyl alcohol, propyl alcohol, butyric and caproic acids. It unites with the alkalies and alkaline earths, the compounds being soluble in water. It prevents the precipitation of copper hydroxide by sodium or potassium hydroxide, and has been recommended for this purpose in the preparation of Fehling's test solution for glucose.

Glycerin is sometimes adulturated with glucose, cane sugar syrup, and water. The first and second of these will usually be easily detected by adding a solution of sodium hydroxide (caustic soda) and enough copper sulphate to impart a blue color, and boiling for a few minutes, when, if these be present, red cuprous oxide will be precipitated. The presence of water may be detected by taking the specific gravity, which should not be below 1.25. Glycerin is the basis of the manufacture of nitro-glycerin, used in various forms of blasting agents, such as "dualine," "dynamite," "giant powder," "rend rock," etc., which are usually composed of nitro-glycerin and some porous substance in powder form.

When glycerin is saturated with gaseous HCl, and then heated for several hours to 100° C., **mono-chlor-** and **di-chlorhydrines** are formed.

$$C_3H_5(OH)_3 + HCl = C_3H_5(OH)_2Cl + H_2O.$$
$$C_3H_5(OH)_3 + 2HCl = C_3H_5OHCl_2 + 2H_2O.$$

Sulphuric acid combines with glycerin to form **glycero-sulphuric acid.** Glacial, or metaphosphoric acid, forms **glycero-phosphoric acid.**

$$C_3H_5(OH)_2OPO = O_2 = H_2.$$

This acid is one of the decomposition products of lecithin and protagon, two complex bodies found in nerve substance, especially of the brain. The acid itself has been found in the brain, nerves, muscles, yolk of egg, bile and pus. The phosphorus present in nerve tissue probably exists in the form of either lecithin or protagon, both of which contain glycero-phosphoric acid. The esters of glycerin and organic acids will be referred to later. (See Neutral Fats.)

Nitro-glycerin, or Glyceryl Trinitrate, $C_3H_5\left\{\begin{matrix}NO_3.\\NO_3.\\NO_3.\end{matrix}\right.$

When glycerin is allowed to flow in a slow stream into a mixture of strong nitric and sulphuric acids, kept cold by a freezing mixture, and the mixture afterward thrown into a large quantity of cold water, there separates out a heavy, colorless, poisonous oily liquid—nitro-glycerin. It crystallizes at — 20° C. (— 4° F.); sp. gr. 1.6. When inflamed in the air, it burns quietly and rapidly, but when ignited by percussion or quick heating, especially in a confined space, it explodes with terrific violence, and hence is much used in blasting. In order to make this explosive agent less dangerous to handle, it is usually mixed with some inert powder, such as clay, diatomaceous earth, sawdust, etc., and is then sold under the name of dynamite, dualine, rend-rock, and giant powder. Under the name of **Spiritus glonoini,** a one per cent. alcoholic solution is official, and is used as a heart stimulant.

Tetratomic Alcohols.—The only one of this class of alcohols of sufficient importance to be mentioned here is **Erithrite** or **Phycite** ($C_4H_6(OH)_4$). It occurs in many lichens and algæ in combination with orsellic acid, as **erythrin.**

Pentatomic Alcohols have not been found in nature, but several have been prepared by the reduction of certain pentoses. They are of scientific interest only.

HEXATOMIC ALCOHOLS.

In the hexatomic alcohols the six hydroxyl radicals are united to six different carbon atoms, so that there must be six carbon atoms in the nucleus. This class of alcohols include—

Mannitol,	$C_6H_8(OH)_6$.
Dulcitol,	$C_6H_8(OH)_6$.
Sorbitol,	$C_6H_8(OH)_6$.
Rhamno-hexitol,	$C_7H_{10}(OH)_6$.

Mannitol-Mannite.—This is the sweet principle of manna, and is found widely distributed in the vegetable kingdom. It ocurrs in celery, fungi, and seaweeds, in the sap of the larch, the exuded sap of the apple, cherry, lime, etc , and the exuded sap of *Fraxinus ornus*, which in the dried state forms commercial manna. It may be prepared artificially by acting upon grape sugar with sodium amalgam (nascent hydrogen), or by the so-called mucous and the butyric fermentations of sugar.

To obtain it from manna, dissolve it in half its weight of boiling water, add some albumen, to clarify, and filter through cloth. On cooling, the mannite separates out. It may also be obtained pure by extracting manna with hot alcohol, and crystallizing. It forms fine, silky needles when crystallized from alcohol, but large, transparent rhombic prisms from the aqueous solution. Mannite is intensely sweet, sparingly soluble in cold, readily soluble in hot water and alcohol, and insoluble in ether. It can readily undergo lactic and butyric fermentations, but not alcoholic. It combines with many metallic oxides, and also forms a large number of compound ethers. Mild oxidation produces **mannitose**, $C_6H_7O(OH)_5$. By further oxidation, it forms mannitic acid, $C_5H_6(OH)_5CO.OH$, and saccharic acid,

$$C_4H_4(OH)_4 \begin{cases} CO.OH \\ CO.OH. \end{cases}$$

Dulcitol—Dulcite—This isomeride of mannite is found in **dulcose**, or dulcite manna, a crystalline substance from Madagascar. It is found in several plants. It has been prepared from milk sugar, by treatment with sodium amalgam. The properties of dulcite resemble those of mannite.

Sorbitol—Sorbite—is a third isomeride of mannite, found in mountain ash berries and in the plum, cherry, apple, and pear. It forms small, colorless needles. It has been prepared synthetically from dextrose. **Rhamno-hexitol** has been prepared from rhamno-hexose, $C_7H_{14}O_6$.

THE CARBOHYDRATES OR SACCHARIDS.

Closely allied to the hexatomic alcohols is a class of important bodies found widely distributed in the vegetable kingdom, known as the carbo-hydrates. They contain, along with carbon, oxygen and hydrogen in the proportion to form water. Until very recently this class of bodies were all natural bodies, formed by plant or animal life. Several of them have since been formed by synthesis, and it now seems likely that at no distant day all of these important food-stuffs may be prepared synthetically. Owing to the discovery of a considerable number of new compounds of this class, the old classification into **saccharoses, glucoses** and **amyloses** has become insufficient. The number of carbon atoms entering into the molecule, instead of being six, or a multiple of six atoms, is now known to vary from three to nine, or some multiple of these. They may be classified into **monosaccharids, disaccharids, trisaccharids** and **polysaccharids.**

The compounds of each of these classes are divided into smaller groups, according to the number of carbon atoms contained in their molecules, into **trioses, tetroses, pentoses, hexoses, heptoses, octoses and nonoses.**

CLASS I.—MONOSACCHARIDS.

Trioses.—Glycerose, $C_3H_6O_3$. Formed by the oxidation of glycerin.

Tetroses.—Erythrose, $C_4H_8O_4$. Formed by the oxidation of erythrite.

Pentoses.—Aribinose, $C_5H_{10}O_5$; **Xylose,** $C_5H_{10}O_5$; **Ribose,** $C_5H_{10}O_5$; **Rhamnose** or **isodulcite,** $C_5H_9(CH_3)O_5$; **Fucose,** $C_5H_9(CH)_3O_5$.

Hexoses.—In this group are two sub-groups,—the aldehydes or **aldoses,** and the ketones or **ketoses.**

The **aldoses** include:—

Dextrose, $C_6H_{12}O_6$, starch sugar, or glucose.
Mannose, $C_6H_{12}O_6$, obtained from manna.
Gulose, a synthetic sugar.
Galactose, from inversion of lactose.
Talose, a synthetic sugar.
Rhamno-hexose, $C_6H_{11}(CH_3)O_6$, a synthetic sugar.

The **ketoses** include:—

Levulose or **Fructose,** from invert sugar.
Acrose, a synthetic sugar.
Sorbinose, from mountain ash berries.

Heptoses.—Manno-heptose, $C_7H_{14}O_7$, obtained from mannose.
Gluco-heptose, $C_7H_{14}O_7$, obtained from glucose.

Octoses.—Manno-octose, $C_8H_{16}O_8$, prepared from mannose.
Gluco-octose, $C_8H_{16}O_8$, prepared from glucose.

Nonoses.—Manno-nonose, $C_9H_{18}O_9$, prepared from mannose.
Gluco-nonose, $C_9H_{18}O_9$, prepared from glucose.

CLASS II.—DISACCHARIDS.

Tribioses, $C_6H_{10}O_5$, and **tetrabioses,** $C_8H_{14}O_7$, are unknown.

Pentabioses, $C_{10}H_{18}O_9$.—**Arabinose.**

Hexabioses, $C_{12}H_{22}O_{11}$.—**Sucrose, Lactose, Maltose, Isomaltose, Trehalose** (mycose), **Melabiose** (eucalyn), **Turanose.**

CLASS III.—TRISACCHARIDS.

Hexatrioses.—Raffinose or meletriose, $C_{18}H_{32}O_{16}$.
Melezitose, $C_{18}H_{32}O_{16}$.

CLASS IV.—POLYSACCHARIDS.

Under this class are grouped a number of carbohydrates of vegetable origin whose molecular formulæ have not been determined. Some of them are crystallizable, as **gentianose** found in gentian root, and **lactosin** found in soap bark, while others are non crystallizable. To this latter group belong the **starches,** the **dextrins** and the **celluloses.**

MONOSACCHARIDS.

These compounds are neutral, colorless, odorless, and sweet-tasting bodies, easily soluble in water, insoluble in ether, and soluble with difficulty in alcohol.

They are easily oxidized, and therefore their alkaline solutions readily reduce certain metallic salts. The most characteristic reduction is afforded by the copper salts, and a solution of copper tartrate in sodium or potassium hydroxide, known as **Fehling's solution,** is used as a test fluid for this class of bodies. Many of them reduce the acetate of copper in a slightly acidulated acetic acid solution, known as **Barfoed's reagent.** The trioses, hexoses, and nonoses readily undergo alcoholic fermentation, while the pentoses, heptoses and octoses do not.

All the monosaccharids give characteristic reactions with phenyl.hydrazin, $C_6H_5NH.NH$, giving precipitates of crystalline **osazones,** when their solutions, slightly acidified with acetic acid, are heated with it. By this means they may be separated from the other classes and from one another, and be identified. A number of these compounds are optically active, and may be estimated by the polariscope.

The **trioses, tetroses,** and **pentoses** are not of sufficient importance to merit here more than a mere mention.

The **tri-saccharids** are not of sufficient importance to merit a separate description.

THE HEXOSES, OR GLUCOSES.

THE ALDEHYDE GROUP.

Dextrose—Glucose—Grape-Sugar, $C_6H_{12}O_6$.—This sugar is widely diffused through the vegetable kingdom, occurring in grapes, honey, in most sweet fruits, sprouting grains, etc., usually mixed with an equal amount of levulose. It occurs in small quantities in the blood, yolk of eggs, and in larger quantity in diabetic urine. It is manufactured on a large scale from corn starch, by boiling with dilute sulphuric acid, neutralizing with lime, drawing off the clear syrup after settling, and evaporating it down to a thick syrup and allowing it to crystallize. Dextrose is less sweet than cane sugar, 2½ parts of the former giving the sweetening power of 1 part of the latter. It is sometimes used to adulterate the light brown varieties of cane sugar. When present in considerable quantities, 5 per cent., it may often be detected by its property of mashing between the teeth instead of crushing like cane sugar. Dextrose crystallizes with some difficulty, and, as usually met with in the market, it does not present to the naked eye a distinct crystalline appearance. It easily undergoes oxidation, especially in alkaline solutions, and thus acts as a reducing agent.

It readily reduces silver, copper, bismuth, and mercury salts in hot alkaline solutions. Silver, if ammonia be present, is reduced in the metallic state and deposited as a brilliant mirror on the surface of the vessel in which it is heated.

The ordinary methods of detection and estimation of dextrose depend upon its reducing power. Fehling's solution, which is in common use, serves as a qualitative and quantitative test for dextrose. It is a solution of 34.64 grms. of pure crystallized copper sulphate, [illegible] grms. of Rochelle salt, and [illegible] grms. of sodium hydroxide in a liter of [illegible] water. [illegible] of this solution is exactly reduced and decolorized by [illegible] grams of dextrose. For qualitative detection, the alkaline solutions of copper, bismuth, indigo-carmine, picric acid, etc., may be used. Dextrose undergoes alcoholic fermentation with great ease and is used in large quantities in the making of beer.

Dextrose also forms compounds with metallic oxides and many salts. When heated, many of these compounds, more particularly those of copper, bismuth, and mercury, decompose, the decomposition being accompanied by a precipitate of either the metal or its oxide.

Dextrose readily undergoes alcoholic, lactic and butyric fermentation. When in contact with finely divided gastric membrane, it is rapidly changed into lactic acid. There is some evidence of the presence of unorganized ferments in the stomach, which can convert lactose and dextrose into lactic acid, and this is probably the origin of a part of the lactic acid found in the gastric contents during digestion. It is an assimilable sugar, though not so readily so as levulose. When injected into the circulation of a dog the greater part of it passes unchanged into the urine.

Phenyl Glucosazone, $C_6H_{10}O_4(C_6H_5N_2H)_2$. — This compound, produced by dextrose with phenyl-hydrazin, occurs in yellow needles. It is prepared under the conditions mentioned under lactose, for the preparation of phenyl lactosazone. The formation of these crystals is employed as a test for glucose in urine. To 50 c.c. of the suspected urine add 1 or 2 grms. of phenyl hydrazin hydrochlorate, 2 grms. sodium acetate, and heat on a water bath for a half hour; or add 10 to 20 drops of pure phenyl hydrazin and an equal number of drops of 50 per cent. acetic acid, and warm as before. On cooling, if not before, the glucosazone separates out as yellow crystalline needles. This test will detect [illegible] grms. of glucose per liter.

Mannose, $C_6H_{12}O_6$, is obtained by the careful oxidation of mannite, and by the hydrolysis of many natural carbohydrates, especially the cellulose from palm nuts, vegetable ivory nuts, etc., by heating them with dilute H_2SO_4. It is a hard, friable powder, easily soluble in water and fermentable with yeast.

THE KETONE GROUP.

Levulose, or **Fructose,** $C_6H_{12}O_6$.—This sugar occurs mixed with dextrose in the natural sources of that sugar, mentioned above. It is obtained with dextrose in invert sugar, prepared by heating cane sugar with dilute acids. It differs from dextrose in being less fermentable and in its rotary power, which is left-handed instead of right-handed; the other differences are of minor importance, except sweetening power, which is greater in this sugar than in grape sugar.

Levulose is easily assimilated when pure, and is completely and easily burned in the body. Its use does not increase the sugar in the urine of diabetics. It has been recently introduced as a sweetening agent for diabetics, under the name of **diabetin.** It yields a compound with phenyl-hydrazin, identical with that derived from dextrose. It forms a compound with calcium hydroxide, which, unlike that yielded by dextrose, is extremely insoluble, and may be employed for the separation of these two sugars.

Acrose, $C_6H_{12}O_6$, is a synthetical sugar obtained by Emil Fischer from acrolein, $CH_2.CH.COH$, an aldehyde obtained by superheating fats or glycerin. It is interesting from the fact that from it mannose, glucose, and levulose have been artificially prepared.

Inosite, $C_6H_{12}O_6.2H_2O = (CHOH)_6 + H_2O$, is optically inactive and does not react with phenyl-hydrazin. It occurs sparingly in the human body. It has been found in the heart, muscles, in diabetic urine, and in that of Bright's disease. It has also been found in the lungs, kidney, spleen, liver, and brain. It occurs in abundance in the vegetable kingdom, especially in unripe beans, from which it may be conveniently prepared. Its sweet taste is its only resemblance to the sugars. It is now believed to be a derivative of benzene, and not a sugar at all.

Pure inosite forms large efflorescent rhombic tables, or occurs in tufted lumps of fine crystals. It is readily soluble in water, slightly so in dilute alcohol, and insoluble in strong alcohol and ether.

Galactose, or **Cerebrose** ($C_6H_{12}O_6$), is formed together with dextrose, when lactose is boiled wtih dilute mineral acids. The two sugars may be separated by crystallization and by the fact that galactose is soluble in absolute alcohol, while dextrose is not. In general reactions and behavior, galactose resembles dextrose, but has a considerably greater rotatory power. It yields, phenyl galactosazone with phenyl-hydrazin, which has the same composition and very similar properties as the corresponding compound of dextrose. Galactose is fermentable with yeast, but less readily than dextrose.

Sorbinose, or **Sorbin** ($C_6H_{12}O_6$), is found in ripe mountain ash berries. It is not fermentable. It is very sweet, and easily soluble in water. It crystallizes in hard, rhombic crystals.

DISACCHARIDS OR SACCHAROSES.

These sugars form an important class of bodies. They are all capable of hydrolysis by dilute acids and certain ferments, yielding monosaccharids.

This process is called inversion. Cane sugar, when inverted, gives dextrose and levulose, lactose gives dextrose and galactose, and maltose gives dextrose only. Cane sugar and lactose are not fermentable, while maltose is. Cane sugar does not reduce Fehling's solution, while the others do.

None of these sugars reduce Barfoed's reagent.

Cane Sugar—Saccharose—Saccharum (U. S. P.)—**Sucrose.**—Cane sugar occurs in the juices of many plants, in most sweet fruits, in the nectar of flowers, and in honey. It is found in large quantity in the juice of the sugar cane (*Saccharum officinarum*), in sorghum (*Sorgo saccharatum*), in beet-root, sugar-maple, and in several species of palm.

Sugar is obtained principally from sugar cane, beet-root, sorghum, and the maple, while some attempts have been made to obtain it from the common maize.

The juice of the sugar cane is expressed by passing the stalks between steel rollers. This is then mixed with milk of lime and heated to boiling to precipitate the coagulable materials, phosphates, etc. These are removed, and the clear liquid evaporated, either in open pans or in vacuum pans under a reduced pressure, to a thick syrup, and then left to crystallize. This "raw sugar" is drained from the "mother liquor," which is further evaporated and again left to crystallize. There is finally left a thick, brown liquid, called molasses, or treacle containing uncrystallizable sugar.

The raw sugar is refined by dissolving it in water, adding lime, and filtering through thick layers of bone charcoal to remove the color. It is then evaporated in vacuum pans and allowed to crystallize.

Pure cane sugar crystallizes in large, transparent, monoclinic prisms, such as are seen in rock candy. It is soluble in one-third its weight of cold, and in all proportions of hot water. It is slightly soluble in weak, but almost insoluble in absolute alcohol. It melts at 160° C. (320° F.), and solidifies, on cooling, to an amorphous mass, called "barley sugar."

The rotary power of sucrose, in solution, is taken advantage of for its quantitative determination.

When cane sugar is boiled with dilute sulphuric acid, it takes up water, and is converted into a mixture of dextrose and levulose, called **invert sugar**.

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6.$$

The same change takes place under the influence of yeast, probably from some soluble ferment contained in it. When heated above its melting point it gives off water, turns dark, and forms a bitter, brown, amorphous substance called **caramel.** At a higher temperature it continues to lose water, decomposes, and gives off inflammable gases, consisting of marsh gas, carbon monoxide and dioxide. At a higher temperature a distillate is obtained, containing aldehyde, acetic acid, acetone, etc. Strong sulphuric acid chars sugar, leaving a black, voluminous mass. Dilute nitric acid oxidizes cane sugar to saccharic acid, then into tartaric, and, finally, oxalic acid. A mixture of concentrated nitric and sulphuric acids forms with sugar a nitrate, $C_{12}H_{18}O_{11}(NO_3)_4$, which is amorphous and very explosive. On heating with sulphuric acid and manganic oxide, a large quantity of formic acid is formed. Cane sugar forms a series of metallic compounds called **sucrates** or **saccharates.** An aqueous solution of sugar will dissolve calcium, barium, magnesium, and lead oxides, and, with an alkali, copper and ferric oxides also. The barium salt crystallizes well.

When cane sugar is injected into the blood-vessels of an animal, it is eliminated in an unaltered condition, and is thus shown to be unassimilated. It may be introduced in large amounts by the alimentary canal, and none of it appears in the urine. From this it appears that it undergoes a change during or before absorption. This change is the result of the action of soluble ferments appearing in the small intestine. Cane sugar readily undergoes lactic fermentation in the presence of sour milk, to which zinc oxide is added for the fixation of the acid.

It does not form a compound with phenyl hydrazin, and by this test it may be distinguished from the other sugars.

Lactose — Milk Sugar — Saccharum Lactis (U. S. P.) ($C_{12}H_{22}O_{11}.H_2O$).—This is an important ingredient of the milk of mammals, and is prepared principally from cow's milk, by evaporating the whey after removing the curd for the manufacture of cheese. Cow's milk contains from 4 to 5 per cent. of sugar, while woman's milk contains from 6 to 7 per cent. It crystallizes in large, hard prisms, has a feebly sweet taste, and is soluble in 6 parts of cold water. Yeast does not ferment it. Lactic and butyric fermentations take place readily. Oxidizing agents yield mucic and saccharic acids. Like cane sugar, it forms compounds with metallic oxides, and reduces alkaline copper solutions.

Ten c. c. of Fehling's fluid, which is reduced by 5 mgr. of glucose, is reduced by 6.7 mgr. of lactose. It does not reduce Barfoed's reagent.* When boiled with dilute mineral acids it yields equal molecules of dextrose and galactose, which are fermentable.

Phenyl Lactosazone ($C_{24}H_{32}N_4O_9$).—This compound of lactose with phenyl-hydrazin is formed by adding to a solution of lactose equal parts of phenyl-hydrazin hydrochlorate and sodium acetate, and heating on a water bath for one-half hour; or by adding 10 to 15 drops of pure phenyl-hydrazin and an equal number of drops of strong acetic acid, and warming. It is soluble in 80 to 90 parts of boiling water and melts at about 200° C. It crystallizes readily in the form of yellow needles, which are usually aggregated into clusters.

Pure lactose is not affected by yeast. Milk is capable of alcoholic fermentation under the influence of certain ferments. This has been employed from the earliest times by the inhabitants of Russia and Asia Minor in the preparation of **kumyss** and **kephir** from mare's milk. In recent years these fluids have attracted much attention for their supposed therapeutic virtues. Very little is known of the real nature of the changes which occur in this fermentation. Kephir ferment is a commercial article in Russia, Austria, and even in this country. Lactose, when injected into the blood-vessels, appears unaltered in the urine. It also sometimes appears in the urine in the early months of lactation or during reabsorption of milk, after weaning. It is, therefore, non-assimilable. But when taken in the alimentary canal it is perfectly assimilated. It has not been observed to undergo any change in the alimentary canal under the action of any of the secretions. Hence, the change probably takes place during absorption through the intestinal walls, as in the case of maltose. When administered in large doses lactose acts as an active diuretic. Milk loses this diuretic effect on being boiled.

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* Barfoed's reagent is composed of 1 part of copper acetate in 15 parts of water. To 200 c. c. of this solution add 5 c. c. of acetic acid containing 38 per cent. of glacial acid.

Maltose — Malt Sugar, $C_{12}H_{22}O_{11}\ H_2O$. — This sugar is formed by the action of malt diastase upon starch. It may also be formed by the action of dilute acids upon starch paste, but in this case the maltose is itself converted into dextrose. This is the chief sugar formed by the action of saliva and pancreatic juice upon starch paste or glysogen, being accompanied in the case of pancreatic digestion by a variable but distinct amount of dextrose. Maltose is very soluble in water. It is also soluble in alcohol, but less so than glucose. It crystallizes, with difficulty, in fine needles. It is not easy to distinguish from glucose by qualitative tests. Its rotary power is + 140, while that of dextrose is 52.5 under the same conditions. With Fehling's solution, the amount of Cu_2O which separates, is only about ⅔ of that which would be reduced by an equal weight of dextrose, or 6.6 parts of dextrose reduce as much copper as 10 parts of maltose. Barfoed's reagent is not reduced by maltose, while it is by dextrose. In this respect maltose resembles lactose, and this test serves to distinguish it from dextrose.

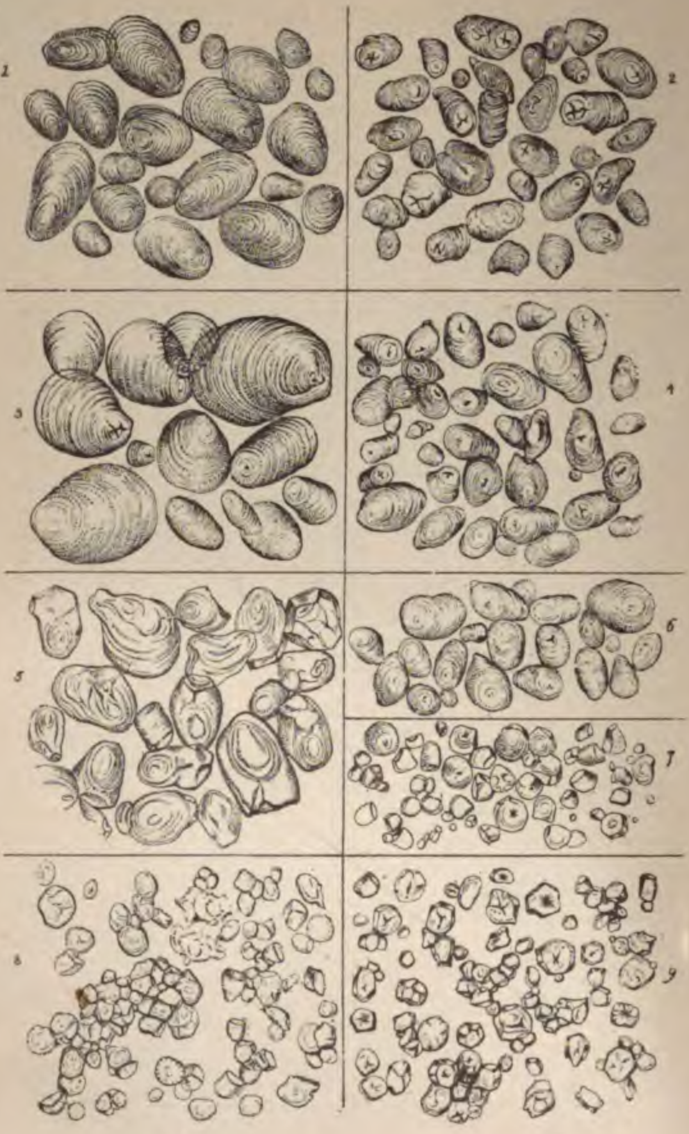
Maltose forms with phenyl hydrazin, in the presence of acetic acid, **Phenyl maltosazone,** $C_{12}H_{20}O_9.(C_6H_5N_2H)_2$. It crystallizes in minute yellow needles and is characterized by being soluble in about 75 parts of boiling water, and is still more soluble in hot alcohol. If maltose be injected into the blood-vessels it appears unaltered in the urine. To be assimilable it must, therefore, be changed before or during absorption.

Iso maltose, $C_{12}H_{22}O_{11}$, is formed, along with maltose, by the action of diastase upon starch, and by the prolonged action of strong hydrochloric acid upon dextrose.

It is found in commercial glucose and in malt beverages. It undergoes fermentation with difficulty. It is intensely sweet.

THE QUALITATIVE DETECTION OF THE COMMON SUGARS. (*Allen.*)

	Dextrose, $C_6H_{12}O_6$.	Levulose, $C_6H_{12}O_6$.	Milk Sugar, $C_{12}H_{22}O_{11} + H_2O$.	Maltose, $C_{12}H_{22}O_{11} + H_2O$.	Cane Sugar, $C_{12}H_{22}O_{11}$.	Dextrin, $(C_6H_{10}O_5)n$.
1. Moisten the solid sugar with water, and stir in the cold with concentrated sulphuric acid (1.84 sp. gr.).	Not affected when pure.	Not affected when pure.	Not affected.	Slightly reddish, or brownish, gradually turning darker.	Charred.	Not affected.
2. Triturate the solid sugar with caustic soda, or boil it with a 5 per cent. caustic soda solution for one minute.	Deep brown coloration.	Deep brown coloration.	Not affected.	Slightly discoloured.	Not affected.	Not affected.
3. To the neutral aqueous solution add a few drops of Fehling's copper solution, and heat to boiling for a few minutes.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.
4. Heat the solution to boiling for half an hour with one-twentieth of its bulk of strong sulphuric acid, neutralize with soda, and heat to boiling with Fehling's solution for a few minutes.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.
5. To a few drops of Fehling's solution add caustic soda and ammonia, heat to boiling, and add the saccharine solution drop by drop, keeping the liquid boiling (Pavy's test).	Liquid decolorised.	Liquid decolorised.	Liquid decolorised.	Liquid decolorised.	No change.	No change.
6. Boil the solution for two minutes with 1 c.c. of a liquid containing 4 per cent. of cupric acetate, and 1 per cent. of acetic acid ($C_2H_4O_2$).	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	No change.	No change.	No change.	No change.
7. Observe the solution in the polarimeter.	Dextro-rotatory.	Lævo-rotatory.	Dextro-rotatory.	Dextro-rotatory.	Dextro-rotatory.	Dextro-rotatory.
8. Heat the solution with diluted acid, as in test 4, and observe again in the polarimeter.	Dextro-rotatory power unchanged.	Lævo-rotatory power unchanged.	Dextro-rotatory power increased.	Dextro-rotatory power diminished.	Dextro-rotatory power changed to lævo-rotatory.	Dextro-rotatory power diminished.



1 Potato Starch
2 Bermuda Arrowroot
3 Tous les Mois
4 St Vincent Arrowroot
5 Sago of Commerce
6 Port Natal Arrowroot
7 Rio Arrowroot
8 Tapioca
9 Maize

(*After Allen*).

POLYSACCHARIDS, OR AMYLOSES.

Starch—Amylum, U. S. P., $(C_6H_{10}O_5)_n$.—This body is found in nearly all plants. It is most abundant in the cereals, rice, potatoes, and the seeds of plants. Starch occurs in the form of microscopical granules inclosed in the cells of the plant where they occur, very much as fat occurs in adipose tissue. The granules, examined under the microscope, are seen to be possessed of a distinct organized structure, which is different in each different kind of starch. They show, under the microscope, several concentric markings, arranged around a nucleus, or hilum, which is situated nearer one edge. The sizes and markings of the starches from the various sources vary sufficiently to admit of identification. This is an important fact in the detection of adulterations in food and drugs. The appearance of a number of the starches of the market, as seen under the microscope, are shown by the plate on next page.

Starch is prepared by grinding the grain or vegetable, and then suspending it in water, or spreading it on a sieve and running water upon it. By this means the starch granules are washed out of the cells, and remain suspended in the water. This milky-looking liquid is allowed to settle, when the starch falls to the bottom. This sediment is taken out, dried, and sent into the market.

Wheat starch is often prepared by suspending the flour in water and allowing it to stand until the gluten is dissolved by putrefactive fermentation, when the starch may be washed and dried.

Starch is insoluble in cold water, alcohol, and ether. Heated with water to a little above 60° C. (140° F.), the contents of the granules swell up, burst the envelopes, and escape into the water. It appears at first as a very fine powder, but afterward disappears and forms an apparent solution, which, if concentrated, forms a jelly-like mass, on cooling, called **starch-paste.** On long boiling, starch enters into a soluble form. The same change is produced by a dry heat of 100° C. (212° F.), by diastase, or dilute sulphuric acid. With diastase it soon passes into the form of maltose and dextrin. It forms metallic compounds with lead, lime, and barium oxides. Soluble starch is precipitated by alcohol and solutions of subacetate of lead.

Starch dissolves in cold, concentrated nitric acid; on the addition of water, **xyloidin,** a white powder, separates. The most characteristic reaction of starch is the dark blue color it forms with free iodine. This blue iodide of starch is easily decomposed, and dissociates when the solution is heated, but reforms on cooling.

Dextrin, or **British Gum,** is an amorphous, yellowish-white, gum-like body, readily soluble in water. It is formed by heating starch above 150° C. (302° F.), or by the first action of malt diastase, or hot dilute sulphuric acid upon starch. This change is a progressive one. When diastase or pancreatic ferment is added to gelatinous starch (starch paste), it is liquefied in a few moments and becomes soluble starch, which is represented by the formula, $10(C_{12}H_{20}O_{10})$. This is gradually hydrated under the action of the ferment, giving rise to eight different steps in the process, and eight different dextrins:—

Soluble Starch, $10(C_{12}H_{20}O_{10}) + H_2O = 9(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ Maltose.
Erythro-dextrin, A, $9(C_{12}H_{20}O_{10}) + H_2O = 8(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ "
Erythro-dextrin, B, $8.C_{12}H_{20}O_{10}) + H_2O = 7(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ "
Acroo-dextrin, C, $7(C_{12}H_{20}O_{10}) + H_2O = 6(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ "

and so on until the final result obtained is—

Acroo-dextrin, F, $2(C_{12}H_{20}O_{10}) + H_2O = 2(C_{12}H_{20}O_{10})$ + no Maltose;

that is, the final result always leaves a portion of dextrin unchanged into maltose. The final result is about 20 per cent. of acroo-dextrin to 80 per cent. of maltose. Pancreatic diastase, however, has the power of slowly changing maltose to dextrose, and the lowest acroo-dextrin to maltose. Iodine gives a reddish color with the erythro-dextrins. It gives no color with acroo-dextrin.

Glycogen $(C_6H_{10}O_5)_n$.—This substance resembles starch, and occurs in the liver of man and several animals, in the embryo, yolk of egg, and some mollusks. It dissolves in cold water to an opalescent solution, but is insoluble in alcohol and ether. In many of its properties it resembles dextrin. Its solutions are dextro-gyrate. A diet of starches, sugars, inulin, glycerin, albumin of egg, fibrin, and casein causes an increase of glycogen in the liver; while inosite, quercite, mannite, gums, and fats fail to do so. Violent exercise, prolonged starvation, or fevers exhaust the liver of sugar. Glycogen of the liver is readily changed to acroo-dextrin, maltose, and dextrose by a peculiar diastasic ferment found in the liver, or by the liver cells. Iodine gives a reddish-brown color with both dextrins and glycogen; but the color returns, with the latter, after discharging it with heat.

Glycogen may be prepared from the liver of an animal, previously fed with copious meals of carbohydrates, by cutting it in small pieces and throwing them into an excess of boiling water, using about 400 c. c. to 500 c. c. for 100 grms. of the liver. After boiling for a short time, the pieces are removed and ground in a mortar to a fine powder, mixed with sand or powdered glass, and boiled again for some time. To clear, the fluid is rapidly cooled, and the proteids precipitated with double iodide of mercury and potassium with acetic acid. The solution is filtered, and the glycogen precipitated by the addition of two volumes of strong alcohol, when it may be separated by filtration and washing with absolute alcohol and ether. Glycogen, when pure, is an amorphous white powder, readily soluble in water.

Cellulose $(C_6H_{10}O_5)_n$.—This forms the principal part of the solid framework of plants. The pure substance may be prepared by treating raw cotton or linen fibre with potassium hydroxide, acids, and ether, to remove foreign matters. It is a white solid, exhibiting the structure of the fibre from which it is obtained. It is slightly soluble in a solution of cupric hydroxide in ammonium hydroxide. On the addition of an acid to this solution it is precipitated as a white amorphous mass. Cellulose is insoluble in water, alcohol, ether, and all ordinary solvents. Strong sulphuric acid dissolves it, and on diluting with water, white flakes separate. When boiled with dilute sulphuric acid, it is converted into dextrin and dextrose.

When cotton-wool is steeped in a cold mixture of 1 part of strong nitric and 3 parts of sulphuric acid for a few minutes, squeezed as dry as possible, placed in fresh acid for 48 hours, then pressed dry, and finally washed thoroughly in water, then in a weak solution of sodium carbonate, it possesses, when dry, great explosive properties, and is called **gun cotton**, $C_6H_7O_2(NO_3)_3$. The appearance and physical properties of the cotton remain unchanged, but it becomes a nitrate of cellulose, the composition varying with the mode of preparation.

Pyroxylin is a nitro-cellulose, containing less NO_3 groups than gun-cotton. It is prepared by dipping cotton into a mixture of 14 parts HNO_3 and 22 parts of H_2SO_4, allowing it to steep for 10 hours, or until it is soluble in a mixture of alcohol and ether (1 to 3), and then removing and washing it in cold water. It is used as a source of **collodion.** A solution of pyroxylin in methyl alcohol, acetone, methyl acetate, or amyl acetate is used as a lacquer for metals. This varnish is transparent, flexible, and adheres well to the metal. Pyroxylin is also used in the manufacture of celluloid. The moistened pyroxylin is intimately mixed with camphor, and then passed through heated rollers to melt the camphor, which in the melted state dissolves the pyroxylin. The mixture may be made transparent, or colored, or mottled by the aid of admixtures of coloring matters. It is soluble in glacial acetic acid, warm nitric acid, and in hot concentrated solutions of NaOH. Ether-alcohol (3 to 1) dissolves both the camphor and pyroxylin, while ether alone dissolves out the camphor. When heated to 125° C. (257° F.) celluloid becomes plastic and can be moulded into any desired shape. It is employed to make combs, brushes, jewelry, etc., imitating coral, tortoise shell, ivory, and other materials.

Collodion is prepared by dissolving 4 parts of pyroxylin in a mixture of 75 parts of ether and 25 parts of alcohol. **Flexible collodion** is a mixture of 92 parts of the above, 5 parts turpentine, and 3 of castor oil. **Styptic collodion** owes its property to 20 per cent. of tannic acid.

If dry unsized paper be dipped into a cold mixture of 2 parts of sulphuric acid and 1 of water for a few seconds, and then washed quickly in cold water containing a little ammonia, it is rendered very tough and strong, and is called **parchment paper.**

Lignin is a substance usually found incrusting the cellulose of most woods. It closely resembles cellulose in composition. It resists the action of dilute acids and alkalies, but is oxidized and dissolved by potassium chlorate and nitric acid.

It is colored an intense yellow by aniline sulphate, and a bright red by a solution of phloroglucin in hydrochloric acid. These tests will detect wood fibre in paper when it is present.

Tunicin or **Animal Cellulose** is a similar substance found in the tissues of some animals.

VEGETABLE GUMS.

The gums are amorphous bodies, more or less soluble in water, but insoluble in alcohol, and are converted into one of the glucoses by dilute H_2SO_4. They are of unknown constitution and are found in plants. They are non-volatile and have little or no taste. They are non crystallizable and eminently collodial. From this fact they are difficult to purify. Many of them appear to be closely related in composition to starch, while others have a different composition. They are distinguished from the sugars by being incapable of fermentation by yeast, and being insoluble in alcohol The gums are distinguished from starch and dextrin, by giving no color with a solution of iodine. They do not yield ammonia when heated with soda lime, which distinguishes them from the albuminoids. They have not been sufficiently studied to admit of accurate classification.

Gum Arabic, or **Gum Acacia**, **Acacia,** U. S. P., is a dried exudation from the bark of different kinds of acacia. Strictly speaking, gum arabic is the generic name. Gum acacia is applied only to the purer qualities employed in medicine. It is obtained chiefly from the Sudan. It occurs in rounded, irregular masses, which dissolve in cold water to form a thick, viscid solution. Gum arabic consists essentially of the calcium salt of arabic acid, or arabin.

Arabic Acid, $C_6H_{10}O_5OH_2$, when heated with dilute H_2SO_4, splits up into a series of glucoses or arabinoses, of which four varieties have been recognized.

Gum-senegal forms yellowish or reddish lumps, often the size of a pigeon's egg. It is less soluble than the true gum arabic, and its solution soon becomes dark in color. Gum arabic should not contain more than 4 per cent. of ash. The powder should not be colored blue (absence of starch) or red (absence of dextrin) by iodine. Its solution should give an acid reaction with litmus paper.

Gum Tragacanth is a gummy exudation from *Astragalus gummifer* and allied species. It occurs in tear-like masses, strings, or bands, which are usually marked with ridges. Gum tragacanth is usually white or yellowish-white in color, but inferior varieties are brown. It is hard, tough, and difficult to powder. It is tasteless and insoluble in alcohol and ether. It is insoluble in cold water, but it swells up and forms a thick, jelly-like mucilage. When diffused through a larger amount of water, it yields a ropy liquid. This liquid usually gives a blue color with iodine, showing the presence of starch of which it contains from five to six per cent. Tragacanth contains about 60 per cent. of a gummy or pectinose body, which yields pectic acid on boiling with water containing 1 per cent. of HCl and about 10 per cent. of soluble gum, probably identical with arabin. The characteristic pectinous constituent of tragacanth is variously known as **tragacanthin, adracanthin,** or **bassorin,** and is believed to have the composition $C_{12}H_{20}O_{10}$. **Metarabin** is another gum, found in the roots of carrots, beets, etc. It is insoluble in water and is converted into arabin by treatment with diluted alkalies.

Cerasin is the insoluble part of the gum of the cherry tree and peach tree. By long-continued boiling with water it yields arabin.

Pectin is obtained by the action of natural ferments on pectose, an insoluble body existing in unripe fruits. It exists ready formed in Irish moss and some other mosses. It is soluble in water, the solution gelatinizing on adding either acids or alkalies. It is precipitated by alcohol. By treating with bases, pectin yields pectates, which, on the addition of hydrochloric acid, give insoluble pectic acid.

Algin is obtained from various seaweeds. It is soluble in cold water, forming viscid solutions which do not gelatinize on cooling.

Carragheen is the mucilaginous constituent of Irish moss (Chondrus U. S. P.). It is soluble in water, and is not precipitated by alcohol.

Vegetable Mucilage occurs in linseed, marshmallow, quince-seed, elm bark, etc. Very little is known of the composition of these bodies.

ETHERS.

A simple ether is an oxide of a hydrocarbon radical. If we substitute a bivalent oxygen atom for one hydrogen atom in each of two similar hydrocarbon molecules, we have a simple ether, thus:

$$\left.\begin{matrix} C_2H_6 \\ C_2H_6 \end{matrix}\right\} \qquad\qquad \left.\begin{matrix} C_2H_5 \\ C_2H_5 \end{matrix}\right\} O.$$

If we suppose that in a molecule of water, HOH, we remove both H atoms, and put hydrocarbon or alcohol radicals in their places, we have an ether. When the two radicals are alike it is a **simple ether**, and when unlike it is a **mixed ether.**

Examples of simple ethers—

$$CH_3 - O - CH_3.$$

Methyl ether or Methyl oxide.

$$C_2H_5 - O - C_2H_5.$$

Ethyl ether or Ethyl oxide.

Example of a mixed ether—

$$CH_3 - O - C_2H_5.$$

Methyl-ethyl ether.

Haloid ethers, so-called, are the addition or substitution products containing one of the halogen elements, as—

$$C_2H_5Br \text{ or } CH_3Cl.$$

Esters or **Compound Ethers** are formed by replacing one of the hydrogen atoms in a molecule of water by a hydrocarbon radical, and the other by an acid radical, as—

$$\underset{\text{Ethyl Acetate.}}{C_2H_5 - O - C_2H_3O.}$$

Formation of Ethers.—Ethers may be formed by the dehydrating action of H_2SO_4 upon the corresponding alcohols.

$$2C_2H_5OH - H_2O = (C_2H_5)_2O.$$

They may also be formed by the reaction of the chloride or iodide of an alcohol radical upon an alcohol in which the alcoholic hydrogen has been replaced by a metal—

$$\underset{\substack{\text{Sodium}\\\text{Ethylate.}}}{C_2H_5ONa} + \underset{\substack{\text{Ethyl}\\\text{Iodide.}}}{C_2H_5I} = \underset{\text{Ethyl Ether.}}{C_2H_5OC_2H_5} + \underset{\substack{\text{Sodium}\\\text{Iodide.}}}{NaI.}$$

$$\underset{\text{Sod. Ethylate.}}{C_2H_5ONa} + \underset{\substack{\text{Methyl}\\\text{Iodide.}}}{CH_3I} = \underset{\text{Methyl-ethyl ether.}}{CH_3OC_2H_5} + NaI.$$

The compound ethers may be formed by warming a mixture of the alcohol and the acid, or alkaline salt of the acid, with sulphuric acid -

$$\underset{\substack{\text{Ethyl}\\\text{Alcohol.}}}{C_2H_5OH} + \underset{\text{Sod. Acetate.}}{NaC_2H_3O_2} + H_2SO_4 =$$

$$\underset{\text{Acetic ether or Ethyl Acetate.}}{C_2H_5 - O - C_2H_3O} + HNaSO_4 + H_2O.$$

Or by the following reaction:

$$\underset{\substack{\text{Ethyl}\\\text{Iodide.}}}{C_2H_5I} + \underset{\substack{\text{Potass.}\\\text{Formate.}}}{KCHO_2} = \underset{\text{Ethyl Formate.}}{C_2H_5 - O - CHO} + \underset{\substack{\text{Potass.}\\\text{Iodide.}}}{KI.}$$

The ethers are abundantly produced by both plant and animal life. Many of the essential oils contain compound ethers. The odors of flowers, of ripening fruits, of perfumes, and the peculiar bouquet of the various alcoholic beverages are principally made up of compound ethers.

The most important class of ethers are the fixed animal and vegetable oils.

Ethers of the Paraffin Series.—Methyl Oxide—Methyl ether, $CH_3—O—CH_3$—is a colorless gas of an ethereal odor, soluble in water, alcohol, and H_2SO_4. It is prepared by the action of H_2SO_4 upon methyl alcohol. It liquefies at —36° C. (—32.8° F.).

Ethyl ether—Ethyl oxide—Sulphuric ether—Æther (U. S. P.)—is prepared by heating a mixture of ethyl alcohol and sulphuric acid, and distilling over the resulting ether.

About 10 parts by volume of commercial alcohol and 12 parts of strong sulphuric acid are introduced into the retort, which is provided with two openings. Into one of these a thermometer is placed, while into the other is inserted a funnel tube. The retort is heated until the thermometer marks 130° C. (266° F.). Alcohol is now allowed to run in slowly through the funnel tube, while the temperature is kept between 130° and 140° C. (266° and 284° F.). The ether distils off with part of the water produced, and a small quantity of alcohol and sulphurous oxide. The crude ether floats upon the water as a distinct layer. To obtain it in a pure state, it is washed with a diluted soda solution, dried over quicklime or calcium chloride, and redistilled by the heat of a water bath. This product is called "washed ether." It still contains some water and alcohol, and for anæsthetic purposes must be again purified by the same process. By the above process, a small quantity of sulphuric acid may be made to etherize a very large quantity of alcohol.

The action takes place in two stages, as follows:—

$$\underset{\text{Alcohol.}}{C_2H_5OH} + H_2SO_4 = \underset{\text{Ethylsulphuric acid.}}{(C_2H_5)HSO_4} + H_2O.$$

$$C_2H_5HSO_4 + C_2H_5OH = \underset{\text{Ether.}}{C_2H_5 — O — C_2H_5} + H_2SO_4.$$

Properties.—Pure ether is a very volatile, mobile, highly refracting, colorless liquid, possessing a characteristic odor and burning taste. Sp. gr. 0.725 to 0.728 at 15° C. (59° F.). It boils at 37° C. (98.6° F.). It is soluble in 10 volumes of water, and in all proportions in alcohol, chloroform, benzene, fixed and volatile oils. It is highly inflammable, burning with a luminous flame; in handling it, therefore, care should be taken not to come near a flame. It dissolves resins, oils, and many other organic bodies. It dissolves iodine, bromine, corrosive sublimate, sulphur, and phosphorus. For anæsthetic purposes, it should not affect blue litmus; it should leave no residue when a quantity is evaporated on a watch glass, nor should it leave a foreign odor;

it should boil in a test tube when the latter is held in the hand, and it should not impart a blue color to ignited copper sulphate (absence of water). Twenty c.c. when shaken with an equal volume of water previously saturated with ether, should not lose more than .2 c. c. in volume. A small quantity of alcohol, less than 4 per cent., is not a serious objection.

It is used in preparing spirit of ether, and spirit of compound ether, or Hoffman's anodyne.

Ether is largely used in medicine as an anæsthetic, and is employed by inhalation, or, for local anæsthesia, is sprayed upon the part. When taken in overdoses it causes death. Patients who have taken an overdose may usually be resuscitated by artificial respiration, or by the use of the induced current applied upon the neck and epigastrium. In cases of death, the odor of ether usually lingers upon the clothing and in the lungs for several hours.

COMPOUND ETHERS, OR ESTERS.

Compound ethers correspond in structure with the salts of the metals in which the metal, or compound radical, is replaced by a hydrocarbon radical.

Thus, sodium acetate corresponds with ethyl acetate—

$$\underset{\text{Sod. Acetate.}}{Na - O - C_2H_3O} \text{ and } \underset{\text{Ethyl Acetate.}}{C_2H_5 - O - C_2H_3O}.$$

Compound ethers may be formed in some cases by the direct action of the acid upon the corresponding alcohol—

$$\underset{\substack{\text{Sulphuric}\\\text{Acid.}}}{H_2SO_4} + \underset{\substack{\text{Ethyl}\\\text{Alcohol.}}}{2C_2H_5 - OH} = \underset{\substack{\text{Ethyl}\\\text{Sulphate.}}}{(C_2H_5)_2SO_4} + \underset{\text{Water.}}{H_2O}.$$

In most cases it is necessary to use some sulphuric acid to take up the water formed by the reaction, in order to form the ethers, and for the same reason we employ the solid salt of the acid we wish to combine with the alcohol.

A second method of preparing these ethers is by first forming a haloid ether with the alcohol radical, and causing a double reaction between this and a silver salt of the acid.

$$\underset{\substack{\text{Silver}\\\text{Nitrate.}}}{AgNO_3} + \underset{\substack{\text{Ethyl}\\\text{Chloride.}}}{C_2H_5Cl} = \underset{\text{Ethyl Nitrate.}}{C_2H_5 - O - NO_2} + \underset{\substack{\text{Silver}\\\text{Chloride.}}}{AgCl}.$$

All compound ethers, when treated with a strong alkali, give up their acids to the alkali, and set free the alcohol, or hydroxide of the hydrocarbon radical. This decomposition is termed **saponification,** by whatever means it is accomplished.

A large number of these compounds are known, but a few only are met with in medicine.

Methyl Nitrate, CH_3NO_3, is a colorless liquid boiling at 66° C.

Methyl Salicylate, $C_6H_4.CO_2H.CH_3$, **Methyl Salicylas** U. S. P., **Artificial Oil of Wintergreen,** is a colorless or yellowish liquid, having the odor and taste of oil of wintergreen (Gaultheria), with the essential constituent of which it is identical. It is identical with the oil of Betula. Its sp. gr. is 1.183 to 1.185, and it boils at 219° to 221° C. (426° to 429.8° F.). It is optically inactive. It is slightly soluble in water, but soluble in alcohol, glacial acetic acid, carbon disulphide, and the volatile oils. It may be prepared by distilling a mixture of salicylic acid, wood alcohol, and strong H_2SO_4

It is employed as a flavoring agent, and to some extent in medicine.

Ethyl Acetate—***Æther Aceticus*** (U. S P.)—**Acetic Ether** ($C_2H_5—O—C_2H_3O$)—is prepared by distilling a mixture of strong sulphuric acid, alcohol, and sodium acetate.

$$\underset{\text{Alcohol.}}{C_2H_5OH} + \underset{\text{Sodium Acetate.}}{Na(C_2H_3O_2)_2} + H_2SO_4 =$$
$$\underset{\text{Ethyl Acetate.}}{CH_3CO - O - C_2H_5} + H_2O + NaHSO_4.$$

The distillate is washed with a solution of calcium chloride and milk of lime, decanted, dried over calcium chloride, and finally redistilled. Acetic ether is a colorless, limpid liquid, boiling at 76° C. (168.8° F) and possessing a pleasant, fruity odor. It dissolves in about 8 parts of water, the water becoming acid from the decomposition of a part of the ether into acetic acid alcohol. It is miscible with methyl and ethyl alcohol with ether in all proportions.

It is a good solvent for the essential oils, resins, morphine, gun cotton, and most other substances soluble in ether.

The refreshing smell of hock-vinegar and some old wines is due to the presence of acetic ether. The ether is inflammable, burning with a bluish-yellow flame and acetous odor.

Ethyl Nitrite, or **Nitrous Ether** ($C_2H_5—O—NO$), is a mobile liquid, boiling at 16.5° C. (62°F.). It has a sp. gr. of 0.947, and is insoluble in water, but freely soluble in alcohol. It is prepared by distilling a mixture of alcohol, potassium nitrite, and sulphuric acid; or by gradually heating a mixture of equal parts of alcohol and strong nitric acid until it begins to boil, then removing the heat and allowing it to distil slowly.

$$2C_2H_5OH + 2KNO_2 + H_2SO_4 = 2C_2H_5NO_2 + K_2SO_4 + 2H_2O.$$

It is purified as described above for the other ethers. Nitro-ethane $C_2H_5{-}N\begin{smallmatrix}=O\\=O\end{smallmatrix}$ is isomeric with the above and differs in physical properties. It boils at 113° C. (235° F.), and is more stable than ethyl nitrite.

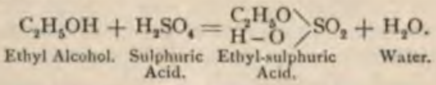
Spirit of Nitrous Ether—Spiritus Ætheris Nitrosi (U. S. P.)—**Sweet Spirit of Nitre**—is a mixture of ethyl nitrite, ethyl alcohol, aldehyde, and acetic ether. It is prepared by adding to 770 grms. of sodium nitrite, dissolved in a liter of water, 550 c.c. of alcohol; the mixture is cooled by ice water, and 520 grms. of H_2SO_4, diluted with 1000 c.c. of water, added slowly through a funnel tube. The resulting ether is then slowly distilled over.

The distillate is washed with ice water, to remove alcohol, and then with a solution of sodium carbonate, and finally dried with potassium carbonate. It is then mixed with 21 times its weight of deodorized alcohol.

Spirit of nitrous ether is a clear, mobile, volatile, pale yellow, inflammable liquid, having a fragrant, ethereal odor and a sharp, burning taste. The sp. gr. is about 0.836 to 0.842 at 15° C. (59° F.). It should boil at about 65° C. (149° F.).

When 5 c.c. of the liquid are placed in a nitrometer with 10 c.c. of a 16 per cent. solution of potassium iodide, and then 10 c.c. of a normal solution of H_2SO_4 added, it should give off not less than 55 c.c. of N_2O_4. (U. S. P. test.)

Ethyl Sulphates.—There are two sulphates of ethyl, the one neutral and the other acid, corresponding to the neutral and acid sulphates. When H_2SO_4 acts upon an excess of alcohol we have the following reaction:



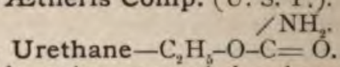
$$\underset{\text{Ethyl Alcohol.}}{C_2H_5OH} + \underset{\substack{\text{Sulphuric}\\ \text{Acid.}}}{H_2SO_4} = \underset{\substack{\text{Ethyl-sulphuric}\\ \text{Acid.}}}{\left.\begin{matrix}C_2H_5O\\ H-O\end{matrix}\right\rangle SO_2} + \underset{\text{Water.}}{H_2O}.$$

This reaction is the first step in the manufacture of ether. On heating with alcohol, this compound breaks up into ether and sulphuric acid.

Ethyl Sulphate, $(C_2H_5)_2SO_4$, is a heavy, oily, yellow liquid, prepared by mixing in a retort equal volumes of alcohol and sulphuric acid, and, after 24 hours, distilling off the contents of the retort at about 150° C. to 160° C. (302° to 320° F.).

$$2C_2H_5OH + H_2SO_4 = (C_2H_5)_2SO_4 + 2H_2O.$$

This oily liquid is known as **heavy oil of wine.** When mixed with an equal volume of ether it forms the **Oleum Ætherium** of the U. S. P. It is used in making the compound spirit of ether. **Spiritus Ætheris Comp.** (U. S. P.).



Ethyl Carbamate or **Urethane**—$C_2H_5\text{–}O\text{–}\overset{\diagup NH_2}{C}= O$. This compound ether is formed by acting upon ethyl carbonate with ammonia at 100° C. (212 F.). Ethyl carbonate is prepared by treating silver carbonate with ethyl iodide—

$$2C_2H_5I + Ag_2CO_3 = (C_2H_5)_2O_2 = CO + 2AgI.$$
$$(C_2H_5)_2CO_3 + NH_3 = C_2H_5 - O - CO - NH_2 + HOC_2H_5.$$

Or, by the action of urea nitrate upon alcohol at a temperature of 120° to 130° C. (248° to 266° F.).

$$\underset{\text{Urea Nitrate.}}{CO(NH_2)_2HNO_3} + \underset{\text{Ethyl Alcohol.}}{C_2H_5OH} = \underset{\text{Am. Nitrate.}}{NH_4NO_3} + \underset{\text{Ethyl Carbamate.}}{NH_2CO - O - C_2H_5.}$$

The resulting urethane is extracted with ether and recrystallized.

Urethane occurs as odorless, colorless, columnar, or tabular crystals, with a taste resembling nitre. It melts at 47° C. (116.6° F.), and distils at 180° C. (356° F.). It is readily soluble in water and most other media.

Tests.—Heated with H_2SO_4 it gives off CO_2 and traces of alcohol. Heated with KOH it gives off ammonia. If 1 grm. be dissolved in 10 c.c. of water, and two grms. of sodium carbonate and a few granules of iodine added, and the mixture gently warmed, iodoform separates on cooling. Urethane is used in medicine as a hypnotic in doses of 1 to 2 grammes.

Somnal is a solution of chloral and urethane in alcohol. Ethyl benzoate, valerianate, butyrate, nitrate, etc., are prepared very much in the same way as the above ethers, using the salts of the acids here indicated with alcohol and sulphuric acid.

Amyl Acetate ($C_5H_{11}—O—C_2H_3O$) is prepared by distilling a mixture of amyl alcohol, sulphuric acid, and sodium acetate. It has a pleasant, ethereal odor.

It is manufactured on a considerable scale for use as a flavoring agent for confectioners.

Amyl Nitrate ($C_5H_{11}—O—NO$) is prepared by passing nitrogen trioxide, N_2O_3, into amyl alcohol. It is a colorless or slightly yellow liquid, and possesses the choking smell of amyl compounds generally. It boils at 96° C. to 99° C. (205° to 210° F.). Specific gravity .872 to .874. Its vapor, when inhaled, produces at first a sense of fulness in the head and dizziness; then flushing of the face, increased heart action, and lowering of the blood pressure and temperature. It may contain as impurities nitric acid, amyl nitrate, amyl valerianate, and hydrocyanic acid.

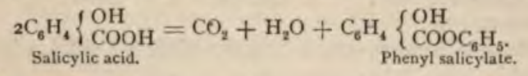
It is almost insoluble in water, but mixes in all proportions in ether and alcohol. It is very volatile even at low temperatures, and is inflammable.

The method of assaying amyl nitrite is the same as that above described for ethyl nitrite; 0.26 grms. should yield about 40 c.c. of gas.

Salol—Phenyl Salicylate, $C_6H_5—O—C_7H_5O_2$—is prepared by heating a mixture of sodium-phenyl, sodium salicylate, and phosphorus oxychloride. The reaction is as follows:

$$\underset{\text{Sod. phenol.}}{2C_6H_5ONa} + \underset{\text{Sod. salicylate.}}{2C_6H_4OHCOONa} + POCl_3 =$$
$$3NaCl + NaPO_3 + \underset{\text{Phenyl salicylate.}}{2C_6H_4OHCOOC_6H_5}.$$

Another method is to heat salicylic acid in a flask to from 220° to 230° C. (428° to 446° F.) in an atmosphere of inert gas, as CO_2, when it loses water and CO_2, and is converted into salol.



$$2C_6H_4\left\{\begin{matrix}OH\\COOH\end{matrix}\right. = CO_2 + H_2O + C_6H_4\left\{\begin{matrix}OH\\COOC_6H_5.\end{matrix}\right.$$

Salicylic acid. Phenyl salicylate.

This ether is found in the market as a white, crystalline powder, almost insoluble in water, having a faint aromatic odor and a slightly salty taste. It is soluble in ether, alcohol, benzene, and fatty oils. It melts to a colorless, oily liquid at 43° C. (110° F.). It is not a very stable compound, and breaks up easily into carbolic and salicylic acids. With fixed alkalies it breaks up into salicylate and an alkali phenol. This change takes place with bile in the duodenum. It is used in medicine as an intestinal antiseptic, and in the treatment of rheumatism.

Salacetol—Acetol Salicylate, $(CH_3COCH_2)CO_2C_6H_4OH$, is a compound recently introduced into medicine as a substitute for salol, from which it differs in having the radical acetol (C_3H_5O) in place of the phenyl radical (C_6H_5).

Salacetol is prepared by heating together monochlor-acetone and sodium salicylate:

$$C_6H_4\begin{cases}OH\\COONa\end{cases} + CH_3COCH_2Cl = C_6H_4\begin{cases}OH\\COO(CH_2COCH_3)\end{cases} + NaCl.$$

Sodium salicylate. Monochlor-acetone. Salacetol.

Salacetol occurs in white shining leaflets, melting at 71° C. (160° F.), very slightly soluble in water, soluble in 15 parts of cold alcohol, in 25 parts of castor oil, or in 30 parts in almond or olive oil. It contains 71.1 per cent. of salicylic acid in combination with the absolutely non-toxic substance, acetol, a homologue of levulose. Salacetol may therefore be regarded as a synthetical glucoside. It is, like salol, decomposed by alkalies into acetone and an alkaline salicylate. It reduces Fehling's solution.

It has been used as an intestinal antiseptic and in rheumatism, both internally and by inunction. It may be given in doses as large as 2 or 3 grams.

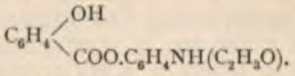
Salicyl-Acetic Acid, $C_6H_4\begin{cases}OCH_2COOH\\COOH\end{cases}$, is closely related to salacetol, although not an ester. It is prepared by the action of monochlor-acetate of sodium upon de-sodium salicylate.

$$C_6H_4\begin{cases}ONa\\CO_2Na\end{cases} + NaCH_2ClCO_2 = C_6H_4\begin{cases}OCH_2CO_2Na + NaCl\\CO_2Na.\end{cases}$$

Di-sod. salicylate. Sodium monochlor-acetate. Sodium salicyl-acetate.

The sodium salt is dissolved in water, and the acid is set free with hydrochloric acid. The acid is said to possess great antiseptic powers.

Salophen—Acetyl-para-amido-phenyl Salicylate—



$$C_6H_4\begin{cases}OH\\COO.C_6H_4NH(C_2H_3O).\end{cases}$$

may be regarded as salol in which an atom of hydrogen in the phenyl group has been replaced by the univalent group $NHCOCH_3$.

Salophen occurs in minute, white, crystalline scales, almost entirely insoluble in water, and free from odor and taste. It is freely soluble in alcohol and ether. The alcoholic solution gives a violet-colored precipitate with Fe_2Cl_6, and a dense white one with bromine water. It melts at 187° C. (368.6° F.). Like salol, it splits up in the body, and is excreted as salicyluric acid, and para-phenol compounds. It is comparatively harmless.

Salol-camphor is prepared by fusing a mixture of 3 parts salol and 2 parts camphor. It is a colorless, oily liquid, soluble in ether, chloroform, and oils.

Fruit Essences.—Many of the compound ethers are found in the essential oils of plants and fruits. Salicylic aldehyde or salicylous acid, $C_6H_4\left\{\begin{matrix}OH\\COH,\end{matrix}\right.$ is the essential oil of meadow-sweet, and may be prepared artificially by the oxidation of salicin. Methyl salicylate, $C_6H_4\left\{\begin{matrix}OH\\COOCH_3,\end{matrix}\right.$ composes almost entirely oil of wintergreen (Ol. Gaultheriæ, U. S. P.), and oil of birch (Ol. Betulæ Volatile. U. S. P.). This last may be prepared artificially by heating chloroform and sodium phenol.

Artificial Fruit Flavors.—These flavoring extracts have come into use extensively in recent years, and are manufactured largely from various mixtures of compound ethers, organic acids, and glycerin. The following formulæ will give some idea of the character of these mixtures: **Pine Apple** consists of chloroform, one part; aldehyde, one part; ethyl butyrate, five parts; amyl butyrate, ten parts, and glycerin, three parts. **Strawberry,** of ethyl nitrate, one part; ethyl acetate, five parts; ethyl formate, one part; ethyl butyrate, five parts; methyl salicylate, one part; amyl acetate, three parts; amyl butrate, two parts; glycerin, two parts. **Pear,** of ethyl acetate, five parts; amyl acetate, ten parts; benzoic acid, one part, and glycerin, ten parts.

The ethers are to be dissolved in pure alcohol (specific gravity .83), and the numbers given indicate the quantity to be added to 100 parts of alcohol by measure. The mixtures, when taken in large quantities, produce deleterious effects; but as the quantities actually used are very small, they probably produce no appreciable effects. Besides the above mentioned and many other "fruit essences," these ethers are also extensively employed to improve the flavor of poor wines, and to fraudulently imitate wines, brandy, rum, whiskies, etc.

Ethers of Glycerin, or Glycerids.—As glyceryl, C_3H_5, or the radical of glycerin, is a trivalent radical, it can and usually does unite with three molecules of a monobasic acid. The compound ethers of glyceryl and the acids of the first or paraffin series, compose most of the natural fixed oils and fats. For this reason the acids formed from this series are called collectively the **fatty acids.** The trinitrate of glyceryl has already been described. The natural fixed oils and fats are composed of mixtures, in most cases, of two or more of these glycerids. The principal glycerids are given below.

NATURAL FATS AND FIXED OILS.

Name.	Formula.	Occurrence.
Monoformin,	$C_3H_5(OH)_2OCHO$,	Artificial ester.
Diformin,	$C_3H_5(OH)(OCHO)_2$,	" "
Monoacetin,	$C_3H_5(OH)_2OC_2H_3O$,	" "
Triacetin,	$C_3H_5(OC_2H_3O)_3$,	*Euonymus europæus.*
Tributyrin,	$C_3H_5(OC_4H_7O)_3$,	Butter.
Trivalerin,	$C_3H_5(OC_5H_9O)_3$,	Solid excrement and dolphin oil.
Tricaproin,	$C_3H_5(OC_6H_{11}O)_3$,	Butter, cocoanut oil.
Tricaprylin,	$C_3H_5(OC_8H_{15}O)_3$,	Fæces, cocoanut oil, butter.
Tricaprin,	$C_3H_5(OC_{10}H_{19}O)_3$,	Cocoanut oil, goat's milk.
Trilaurin,	$C_3H_5(OC_{12}H_{73}O)_3$,	Cocoanut, palm-nut and bayberry oils.
Trimyristin,	$C_3H_5(OC_{14}H_{27}O)_3$,	Cocoanut oil, palm-nut oil, nutmeg butter, cow's butter, and goose fat.
Trilinolein,	$C_3H_5(OC_{16}H_{31}O)_3$,	Linseed, poppy, sunflower, hemp-seed oils.
Triolein,	$C_3H_5(OC_{18}H_{33}O)_3$,	Oils (Olive oil).
Tripalmatin,	$C_3H_5(OC_{16}H_{31}O)_3$,	Oils and Fats (Palm oil).
Tristearin,	$C_3H_5(OC_{18}H_{35}O)_3$,	Animal Fats (Tallow).

Almost all the fats and fixed oils are compound ethers of glyceryl, C_3H_5'''. They are found in both the animal and vegetable kingdoms. Some are liquid, while others are solid. Some oils remain permanent in the air, like olive oil, while others oxidize and thicken, like linseed and poppy oil. These latter are called siccative, or drying oils. The fats are insoluble in water, difficultly soluble in alcohol, but soluble in ether, petroleum naphtha, and carbon disulphid. The composition of natural oils has been partially considered while speaking of the fatty acids. So far as known, no fat consists purely of one substance, but of a mixture of oleate, palmitate, and stearate of the triad radical, glyceryl, C_3H_5.

These fats are decomposed by heat; acrolein being one of the products.

Tristearin, or **Stearin,** $C_3H_5(C_{18}H_{35}O_2)_3$, is found in the more solid fats. It may be separated from the other principles, by melting tallow with turpentine, when the stearin remains in solution, while the olein and palmitin are precipitated.

By adding water to this liquid, the stearin may be separated. It fuses at 71° C. (160° F.), and solidifies again at 50° C. (122° F.).

Tripalmitin, $C_3H_5(C_{16}H_{31}O_2)_3$, is the chief constituent of mutton fat, lard, and human fat. It is more soluble in alcohol and ether than stearin. It crystallizes in fine needles, and its melting point is at 46° C. (115° F.).

Triolein, $C_3H_5(C_{18}H_{33}O_2)_3$, is the fluid constituent of most fats and oils. When pure, it is a colorless fluid, becoming yellow on exposure to the air. It may be obtained from olive oil by treating it with cold alcohol, cooling the solution to 0° C. (32° F.) to separate the palmitin, and adding water to the alcoholic solution to precipitate the olein. Olein is more abundant in vegetable than in animal oils.

When treated with hot alkalies or superheated steam, the fats are saponified. Most fats decompose slowly in contact with air, and become rancid. In the process of digestion they are partially saponified and then emulsified; *i. e.*, broken up into minute drops. The active agents in this change are the bile and pancreatic secretion. The emulsification and absorption of partially saponified fats takes place with greater ease than with pure fat; hence, a slightly rancid oil is more easily assimilated than a fresh one.

The sources of fat in the human body are: 1st, the fat taken as food; 2d, the decomposition of proteids; 3d, the carbohydrates, a portion of which are converted into fat.

These oils are termed "**fixed**" to distinguish them from the volatile or essential oils described in another place. When rubbed upon paper they render it translucent, the spot remaining more or less permanent. They are, when pure, nearly tasteless and odorless, unctuous to the touch, insoluble, and float upon water. Some of them absorb oxygen when exposed to the air, and become thick and gummy. These are called **drying or siccative** oils. The fixed oils are usually obtained by pressure with or without the aid of heat.

Olive oil—oleum olivæ (U. S. P.)—is a well-known oil expressed from the fruit of the olive tree. It is a yellow or greenish-yellow oil, almost odorless, and of a bland, sweetish taste. The finest grades have a greenish tinge, and are prepared by submitting the fruit to cold pressure. Olive oil is frequently adulterated, chiefly with poppy oil, sesame oil, cotton-seed oil, and peanut oil. The method of detection of adulterations will be seen by reference to the table on p. 391. The sp. gr. of olive oil is .915 to .918. It is very sparingly soluble in alcohol, but readily soluble in ether, chloroform, or carbon disulphide. When cooled to about 10° C. (50° F.) it begins to deposit crystalline particles, and at 0° C. (32° F.) it forms a white, granular mass.

Almond Oil—oleum amygdalæ expressum (U. S. P.)—is a fixed oil expressed from bitter or sweet almonds, a clear, pale straw-colored, or colorless oil, almost inodorous and having a mild, sweet taste. The pure oil has no odor of bitter almonds. Sp. gr. is from .915 to .920. It is slightly soluble in alcohol, and it is readily soluble in ether and chloroform. If 2 c.c. of the oil be shaken with 1 c.c. of fuming nitric acid and 1 c.c. of water, a white or reddish-brown mixture should be formed, which should separate, on standing some hours, into a white, solid mass and scarcely colored liquid.

Earth nut or Peanut oil—arachis oil—is obtained from the nuts of *Arachis hypogea*, the oil being chiefly expressed in France. The nut contains about 45 per cent. of the oil. It is of a pale greenish-yellow color, of a distinctly nutty flavor and smell, and is used very largely in the adulteration of olive oil, lard oil, and other oils.

Cotton seed oil—oleum gossipii seminis (U. S. P.)—is a fixed oil expressed from the seeds of *Gossipium herbaceum*, or the cotton plant, and subsequently purified. It is a pale yellow oil without odor, and having a bland, nut-like taste. Its sp. gr. is 0.920 to 0.930. It is largely employed as a substitute for, or an adulterant of, olive oil. It is largely used as a substitute for lard in cooking, in the manufacture of butterine and soap, and for adulterating other oils.

Sesamé or teel oil—benne oil—oleum sesami (U. S. P.)—is a fixed oil expressed from the seeds of *Sesamum indicum*. It is a yellow, inodorous, and bland oil resembling cotton-seed oil, and used for the same purposes. It is an imperfect drying oil, and does not readily turn rancid. Its behavior with reagents will be seen by reference to the table.

Cod-liver oil—oleum morrhuæ (U. S. P.)—is a fixed oil obtained from the fresh livers of the cod, *Gadus morrhua*. It is obtained by pressure, either with or without the aid of heat. Several qualities of cod-liver oil are recognized in commerce; a pale oil of a straw-yellow color, a pale brown oil of inferior quality, also used in medicine, and a dark brown variety obtained by roughly boiling down the livers and known as **tanner's oil.** When fresh, the best grades of oil are almost colorless and limpid, with a slight odor and taste and a faint acid reaction. On standing, the fishy taste and odor, as well as the acid reaction, increase. Cod-liver oil consists essentially of several glycerids, the chief one being olein, with variable quantities of myristin, palmitin, stearin, with small quantities of cholesterin and free fatty acids. Cod-liver oil contains traces of iodine and sometimes bromine, but the form in which these elements exist is unknown. A peculiar acid called **gaduic acid,** and another substance called

gadium, and two alkaloids, **asselin** and **morrhuin**, have been found. Gautier has obtained butylamin, amylamin, hexalamin and hydrodimethyl-pyridin. To which of these substances cod-liver oil owes its value as a therapeutic agent, is still a matter of doubt. Heyerdahl claims that when made from fresh livers and without exposure to air, it does not contain any of these alkaloids. He finds that it does contain two fats, *therapin* and *jecolein*. Therapin, $C_3H_5(OC_{17}H_{25}O)_3$, comprises about 20 per cent. of the oil, while jecolein, $C_3H_5(OC_{34}H_{66}O)_3$, forms about the same amount; the rest he has not thoroughly studied. The property which is probably the chief recommendation for its use, is the facility with which it is digested or assimilated. This characteristic is not due to the traces of biliary compounds, which are nearly always present. It may in part be due to the readiness with which cod-liver oil becomes rancid or saponifies, as slightly rancid oils are more easily emulsified than neutral oils, and as it very easily saponifies, this would favor its emulsification and absorption. Cod-liver oil is seldom adulterated.

Linseed oil—flaxseed oil—oleum lini (U. S. P.).—It is a dark-yellow fixed oil, expressed from ground linseed without the use of heat. It has a characteristic disagreeable odor and taste. Linseed oil consists of about 80 per cent. of linolein with smaller quantities of olein, myristin, and palmitin. Linolein is a glycerid of linoleic acid. The drying property of linseed oil is due to the presence of linolein, which absorbs oxygen from the air and is converted into a gummy mass resembling resin. The varieties of linseed oil recognized in commerce are raw, refined, artists', and boiled. The tendency of linseed oil to oxidize is much increased by heating it to a high temperature, while passing a current of air through and over the oil, and subsequently increasing the temperature until the oil begins to effervesce. The temperature employed is from 130° C. (266° F.) upward. This process is termed boiling the oil. The oil thus treated is called boiled oil. By continued boiling, the oil becomes very thick and may be drawn out into elastic threads. This process is used in the manufacture of printing ink. By adding litharge, ferric oxide, or manganese oxide to the oil during the boiling process, the oxidation and consequent drying properties of the oil are increased. The salts of lead and manganese are most employed in the manufacture of "driers" for linseed oil.

Castor Oil—Oleum Ricini (U. S. P.)—is usually obtained by the extraction of the oil by the expression of the seeds of *ricinus communis*, which contain nearly one-half their weight of oil. If not clear, the oil is treated with animal charcoal or magnesia, and filtered. It is a thick, viscid, transparent, colorless or greenish yellow liquid, having a faint odor and disagreeable taste. At a low temperature it thickens and deposits white granules, and at about —18° C. (—0.4° F.) it solidifies. Castor oil differs from most other fixed oils by its density, viscosity, and its ready solubility in alcohol and insolubility in naphtha. Its sp. gr. is .950 to .970. Nitric acid attacks it energetically, and converts it into suberic acid. Ammonia precipitates from it a crystalline solid. It is used in medicine as a laxative.

Palm Oil has a reddish-yellow to a brown color, and varies in consistency from that of soft lard to that of tallow. As met with in commerce, it is frequently contaminated with water and solid impurities, and is more or less rancid.

Cacao Butter—Oleum Theobromatis—is a fixed oil expressed from the seeds of *Theobroma cacao*. It is a yellowish-white solid, having a faint, agreeable odor and a bland, chocolate-like taste. Sp. gr. is from .970 to .980. It is readily soluble in chloroform and ether, and is soluble in 120 parts of boiling absolute alcohol or 100 parts of cold alcohol. It does not easily become rancid. Its fusing point is between 30° and 33° C. (86° to 91.4° F.). It is a brittle solid at ordinary temperatures.

Croton Oil—Oleum Tiglii—is expressed from the seeds of *Croton tiglium*. It is a pale yellow or brownish-yellow, somewhat viscid, and slightly fluorescent liquid, having a slight fatty odor and a mild, oily, afterward acrid and burning taste. Croton oil contains, besides the glycerides of oleic, crotonic, and fatty acids, a peculiar principle called crotonol, to which the oil owes its vesicating properties. When applied to the skin, it produces a pustular eruption, and when taken internally is a drastic cathartic. The oil has an acid reaction to litmus paper. It is soluble in alcohol, its solubility increasing with age. It is very soluble in ether, alcohol, chloroform, and in the fixed and volatile oils.

Neat's-Foot Oil is obtained by the action of boiling water upon the feet of cattle, horses, sheep, and other animals. It is a straw-yellow, odorless, nearly tasteless liquid. It is not readily prone to rancidity.

Lard Oil—Oleum Adipis (U. S. P.)—is extracted from lard at a low temperature. It is a light yellow, transparent oil, used in cooking, soap making, and in artificial butter, or butterine. It is very frequently adulterated, principally with cotton seed and other seed oils, rape oil, earth, nut, etc.

Tallow is the fat of the ox and sheep, obtained by gentle heat. It is a white or yellowish-white brittle solid, used largely in the manufacture of soap and candles. Tallow oil, or **oleo oil,** is obtained by expression with gentle heat, the more liquid portion running out, and the more solid portion remaining behind in the press. This oil is especially prepared for the manufacture of **oleomargarine.**

Butter consists of a mixture of stearin, palmitin, and olein not soluble in water, and the glycerids of butyric, caproic, caprylic, and capric acids. These last acids are soluble and volatile. Oleomargarine, butterine, suine, etc., are artificial mixtures of butter with foreign fats, made to imitate butter.

The principal foreign fats employed are lard, beef oil, cotton seed, sesamé, and similar oils. The usual method of manufacture is to melt the foreign fats, deodorize them, when necessary, with nitric acid, then either to mix them with genuine butter, or churn them with milk. The mixture usually has a melting point above or below that of genuine butter.

Melting points of various fats:—

Butterine,	31.3° C. (88.5° F.).
Cacao butter,	34.9° C. (94.7° F.).
Butter (average),	35.8° C. (96.6° F.).
Beef dripping,	43.8° C. (111.1° F.).
Veal dripping,	47.7° C. (118° F.).
Lard,	42° C. to 45° C. (107.5° to 113° F.).
Mutton fat,	50° C. to 51° C. (122° to 123.8° F.).
Tallow,	53° C. (127.4° F.).

A low melting point generally indicates butterine, or vegetable oils, while a high one indicates the presence of animal fats.

The detection of foreign substances in butter is a matter of considerable importance, owing to the fact that certain countries have laws prohibiting the sale of artificial butter, or at least restricting its sale.

The modern butter substitutes are close imitations of natural butter, and can only be detected by chemical processes dependent upon the difference in chemical composition of butter fat and other animal or vegetable oils. The butter fat is saponified with a solution of KOH, the soap thus produced is again decomposed with a mineral acid, and the fatty acids are separated. Stearic, oleic, and palmitic acids are insoluble in water, while butyric acid and certain others are soluble. Butter fat when thus treated yields from 5 to 8 per cent. of soluble acids and from 85.5 to 88.5 per cent. of insoluble acids. The sum of the insoluble and soluble fatty acids should always amount to fully

94 per cent. of the fat taken. The other fats and oils, when saponified by this method, yield mere traces of the volatile or soluble fatty acids, and from 95.5 to 97.7 per cent. of insoluble acids. These variations are taken advantage of for the identification of genuine butter or the detection of mixtures. In actual practice 2.5 grms. of the purified butter fat is taken and saponified with KOH, the soap decomposed with diluted H_2SO_4, and the mixture submitted to distillation. The soluble or volatile acids distil off, and are estimated by titration with a standard alkali. From the amount of alkali required to neutralize the volatile acids, the quantity or percentage may be calculated. The insoluble acids remain behind in the distilling flask. If it be desired to do so, they may be filtered out and weighed. Another method that is sometimes employed for the detection of adulteration in butter is the amount of alkali, KOH, required to saponify a known weight of butter. This is known as its saponifying equivalent. It is determined by adding to a known weight of the purified butter fat an excess of standard solution of KOH, and heating until saponification is complete. The excess of KOH is then estimated by a standard acid. The difference between that added, and the free alkali remaining, gives that in combination with the fatty acids of the butter, or the saponifying equivalent. The amount of alkali required for the saponification of butter is much greater than that of most other oils. Another method which is depended upon to distinguish butter from other fats or oils, is the amount of iodine or bromine that a given weight of butter fat will absorb under prescribed conditions. For particulars concerning these various processes we must refer the student to special works on the subject.

Identification of Fixed Oils.—Various methods have been devised for the identification of fixed oils and fats. Some of these depend upon the separation of the fat into its constituents, and the quantitative estimation of these constituents. These processes are rendered necessary because of the extensive adulteration to which commercial oils and fats are subjected. Some of these processes are designed especially for the detection of the falsification of butter. Others are applicable only to the commercial oils other than butter. One of the first characteristics of oil is its sp. gr., which is usually determined by the use of the sp. gr. flask, the method of using which has been described in Part I. In the first column of the table, page 391, will be found the sp. gr. of the principal oils there mentioned. The liquefying temperature is one characteristic property of oils which is made use of for their identification. These temperatures are given in the third column of the said table. Of the chemical methods that are employed for the identification of fixed oils, only the simpler ones can be here described.

The rise of temperature which ensues on treating a fixed oil with H_2SO_4, is the measure of the extent or intensity of the chemical reaction between the two. The rise of temperature has been taken advantage of by Maumené for the identification of many of the fixed oils. It is found that with a given oil the rise is fairly uniform. The method of applying the test is as follows: 50 grms. of an oil are weighed into a 4-oz. beaker. The beaker is placed in a cotton-wool nest, to prevent conduction of heat. The temperature is carefully observed. Ten c.c. of concentrated sulphuric acid, of the same temperature as that of the oil, are now allowed to run into it during the space of about one minute, the mixture being constantly stirred with the thermometer until no further rise of temperature ensues. The rise of temperature may now be readily observed. In the fourth column of the table are given the changes in temperature of the various oils, when the test is carried out according to directions.*

With some oils, sulphuric acid gives characteristic colorations. The next two columns of the table show the effect produced in placing a drop or two of sulphuric acid in the center of about 20 drops of the oil, and observing the color before and after stirring. The colors produced by different samples of the same kinds of oils are liable to some variations from those indicated in the table. Many of the fixed oils give characteristic color reactions with nitric acid as well as sulphuric acid. The method of applying the test is to agitate together from 3 to 5 c.c. of the oil with 1 c.c. of nitric acid of sp. gr. 1.32 Heat the two for five minutes in boiling water and then take it out and observe the color of the oil from time to time for an hour and a half. If the acid be of higher sp. gr., it will be unnecessary to apply the heat. The colors given by this test are to be found in the last column of the table opposite.

The elaidin reaction is also a characteristic test for many of the fixed oils It depends upon the action of nitrous acid upon the oleic acid of the oils, by which it is changed into elaidic acid, which is solid at ordinary temperatures. The best method of obtaining this reaction is with the following solution:

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* NOTE.—Hehner and Mitchell have recently proposed the use of 1 c.c. of bromine, and 1 c.c. of oil dissolved in 10 c.c. of chloroform. They claim better results with bromine than with sulphuric acid.—(Analyst, July, 1895, p. 146.)

TABLE FOR THE IDENTIFICATION OF THE PRINCIPAL FIXED OILS.

REAGENTS AND CONDITIONS.

NAME OF OIL.	SPECIFIC GRAVITY AT 15° C.	SOLIDIFYING TEMPERATURE, C.	HEAT DEVELOPED. 50 GMS. OIL, 10 C. C. H_2SO_4 at 20° C.	H_2SO_4 COLOR TESTS. 1 TO 2 DROPS. 20 GTT. OIL.	SAME AFTER STIRRING.	COLOR TEST WITH HNO_3. 3 TO 5 DROPS OIL. 1 DROP ACID. SP. GR. 1.32.
Olive,	.914 to .917.	+ 4 to 6.	40° C. to 43° C.	Yellow-green brown.	Light brown or olive green.	Colorless or yellow to green
Almond,	.914 to .920.	— 10 to 20.	52° C. to 54° C.	Yellow or colorless.	Dark yellow brown.	Colorless changing to solid.
Cotton seed,	.922 to .930.	1 to 4.	74° C. to 77° C.	Bright red.	Dark red-black.	Red or orange.
Sesamé (Teel Oil),	.921 to .924.	+ 5 to —5.	65° C. to 68° C.	Brown.		Yellow to orange.
Linseed,	.930 to .937.	— 20 to —27.	103° C. to 111° C.	Brown, hard clot.	Mottled-brown.	Red or orange.
Castor,	.950 to .970	— 18.	46° C. to 47° C. (Allen 65).	Yellow to pale brown	Nearly colorless to pale brown.	Transient yellow or orange.
Croton,	.942 to .955.					
Linseed (boiled),	.939 to 950.			Hard brown clot.	Mottled dark brown.	Red or orange.
Cacao Butter,	.995 at 98° C. = .857	30 to 34.				
Cocoanut,	at 98° C. .868° to .874.	20 to 28.	26° C. to 27° C.			
Neat's Foot,	914 to .916.	Below 0° C.	43° C.			
Lard,	.915.	4 to 10.	41° C.	Greenish yellow to brown.	Mottled or dirty brown.	Colorless or transient yellow.
Cod Liver,	.925 to .931.		102 - 113° C.	Dark red spot with purple streaks.	Purple to brown or reddish.	Brown red.
Bees' Wax,	.959 to .969 (at 98° C. .819 to .829).	62 to 64.				

1 c.c. of mercury is dissolved in 12 c.c. of cold concentrated nitric acid. 1 c.c. of this freshly made solution is then shaken in a wide-mouth stoppered bottle with 25 c c. of the oil to be tested, the agitation being kept up at intervals for from one to two hours. When treated in this manner oils consisting of nearly pure olein give a solid product of greater or less consistency. Olive oil is remarkable for the firmness of the lemon-yellow elaidin production. The behavior of the more important fixed oils when tested in this manner is as follows:—

Elaidin Test.—Behavior of most important fixed oils.

(*a*) A solid, hard mass:

Olive, almond, arachis, lard, sperm, and sometimes neatsfoot.

(*b*) A buttery consistency:

Neatsfoot, mustard, sometimes sperm, arachis and rape.

(*c*) A buttery mass separating from a liquid:

Rape, sesamé, cotton-seed, cod-liver, seal, whale, and porpoise.

(*d*) Liquid products:

Linseed, hempseed, walnut, and other drying oils.

Fat in the Human Body.—Fats which occur in the animal body are chiefly mixtures of triolein, tripalmitin, and tristearin in varying proportions with small quantities of tricaproin and trivalerianin. The normal fat in each animal, or class of animals, is characteristic in its composition. Thus, in the fat of man and the carnivora, palmitin is in excess over the other two. In the fat of herbivora, stearin predominates, and in that of fishes, olein. The fat of butter, as seen above, contains several other glycerids in addition to these three. The fat that is accumulated in the animal body during fattening cannot be accounted for by the fat given as food. A large part of it may come from the conversion of proteids and carbohydrates into fat. The manner in which this conversion takes place has been the subject of considerable dispute. The belief now is, however, that both proteids and carbohydrates can give rise to the production of fat in the animal body. The total amount of fat in the human body varies within wide limits, but from 3 to 5 per cent. may be taken as a fair average It is generally greater in women and children than in men. It is generally greater in middle age than during old age, although sometimes this rule is reversed. The object of the storage of fat in the human body, is to provide a surplus of heat-producing elements for periods of starvation and disease. It also serves to lubricate the different organs, to give rotundity to the form, and to protect the internal structure from sudden changes of temperature, owing to its non-conductivity of heat.

The principal service of fat in the economy is as a producer of heat and energy, by its oxidation. In wasting diseases and starvation, the fats previously stored up are rapidly consumed to sustain the body. In cold climates, therefore, more fats are demanded than in temperate or hot climates. When fat is taken in excess of that needed by the body, it is either discharged in the fæces, or it is absorbed and stored up as fat.

Soaps.—Soaps are metallic salts of the fatty acids, *i. e.*, oleic, palmitic, and stearic. Those of potassium, sodium, and ammonium are soluble in water; those of the other metals are insoluble. Hard soaps are salts of the fatty acids with sodium; soft soaps are salts of potassium. Soaps are made from almost any fat, but the best varieties are made from lard, olive, peanut, or palm oils. Cocoanut and palm oil soaps are much used at sea, on account of their property of dissolving in salt water. Castor oil is extensively employed for making transparent toilet soaps, and now very extensively used for soap-making. Lard soaps are very white, solid, inodorous, and valuable for toilet use. Ordinary yellow soap is made by saponifying tallow or palm oil with soda. More or less resin is often added, but the use of too large a proportion renders the soap dark. The principal soaps of commerce contain either an excess of unsaponified oil or fatty acid, on the one hand, or an excess of alkali on the other. The alkali may be either as a carbonate or caustic alkali. Such soaps are said to be alkaline soaps. Small quantities of foreign substances are frequently added to soaps, as coloring, perfume, or medicinal agents. Medicated soaps are now sold, which contain a considerable proportion of medicinal agents, such as carbolic, salicylic, or cresylic acids, thymol, tar, sulphur, ichthyol, naphthaline, camphor, etc. An excess of glycerine is sometimes added, which is a valuable ingredient in certain soaps. In the manufacture of soap, the alkali is either added to the fat previously saponified with superheated steam, or to the free fatty acids. In the first case the glycerin is partially left in the soap, in the second the glycerin has been removed. After the formation of the soap, it is separated from the solution either by evaporating down and allowing it to solidify, or by precipitating it from its solution by the addition of salt. The flaky precipitate is separated, melted, and cast into moulds.

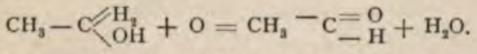
White Castile Soap—Sapo (U. S. P.)—is a soda soap made from olive oil. It is strongly alkaline, hard, yet easily cut when fresh, having a faint, peculiar odor free from rancidity, and has a disagreeable alkaline taste. It is soluble in water and in alcohol, more readily with the aid of heat.

Soft Soap—Green Soap—Sapo Viridis (U. S. P. '80)—**Sapo Mollis** (U. S. P. '93)—is a potassium soap made from linseed oil. It is a soft, unctuous mass of a yellowish-brown color, soluble in about 5 parts of water to a clear liquid. It is also readily soluble in alcohol.

Lead Soap—Lead Plaster—Emplastrum Plumbi (U. S. P.)—is a soap prepared by saponifying olive oil with oxide of lead. It is a yellowish-white, pliable or tenacious, but not greasy mass, gradually acquiring a brownish color on exposure to the air. It is insoluble in water, but is soluble in benzene and chloroform. When a solution of a soluble soap is added to a water containing the heavier metals in solution, an insoluble soap is usually produced. Hard waters usually owe their hardness to the salts of calcium and magnesium. The soaps produced in this case are the insoluble calcium and magnesium soaps. Acids decompose soaps, liberating the fatty acids and forming other salts with the metal.

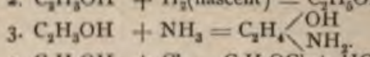
ALDEHYDES.

The aldehydes are compounds formed by the oxidation of the primary alcohols. They differ from the corresponding alcohols by having two atoms of hydrogen removed; thus ethyl alcohol forms ethyl or acetic aldehyde:—



$$CH_3-C\begin{matrix}\diagup H_2\\ \diagdown OH\end{matrix} + O = CH_3-C\begin{matrix}=O\\ -H\end{matrix} + H_2O.$$

By oxidation aldehydes yield the corresponding acids It will be observed that, as two atoms of hydrogen have been removed without putting any atoms in their places, aldehydes are unsaturated bodies. On this occount, they are very liable to undergo changes with reagents. They are especially prone to undergo oxidation to produce acids, and therefore act as strong reducing agents. They can also take up hydrogen, when treated with sodium amalgam, and regenerate the alcohol. They combine with ammonia to form **aldehyde ammonias**, and with the acid sulphites of the alkalies to form crystalline compounds. Aldehydes unite with hydroxylamin, NH_2OH, to form *oximes* and with hydrazines to form *hydrazones*. They restore the red color to magenta (rosanilin hydrochlorate) which has been reduced and decolorized with sulphurous acid. This is used as a test for aldehydes in general. With chlorine and bromine they unite to form the chloride or the bromide of the oxygenated radical. With H_2S they form sulphaldehydes.

1. $2C_2H_3OH + O_2 = 2C_2H_3OOH.$
2. $C_2H_3OH + H_2(\text{nascent}) = C_2H_5OH.$
3.  $C_2H_3OH + NH_3 = C_2H_4\begin{matrix} / OH \\ \backslash NH_2. \end{matrix}$
4. $C_2H_3OH + Cl_2 = C_2H_3OCl + HCl.$
5. $C_2H_3OH + H_2S = C_2H_3SH + H_2O.$

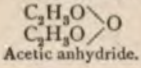
Preparation.—Formaldehyde and polymers of this compound (glucose, etc.) are formed in growing plants. (See part V.)

2. The aldehydes may be formed artificially by partial oxidation of primary alcohols.

$$2C_2H_5OH + O_2 = 2C_2H_3OH + 2H_2O.$$

3. They may also be prepared by the action of nascent hydrogen (sodium amalgam) upon the chlorides or anhydrides of the corresponding acids.

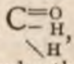
$$\underset{\text{Acetyl chloride.}}{C_2H_3OCl} + H_2 = \underset{\text{Acetic aldehyde.}}{C_2H_3OH} + HCl.$$



$$\underset{\text{Acetic anhydride.}}{\begin{matrix} C_2H_3O \\ C_2H_3O \end{matrix}\Big> O} + 2H_2 = \underset{\text{Acetic aldehyde.}}{2C_2H_3OH} + H_2O.$$

4. By distilling a mixture of the calcium salt of the corresponding acid with calcium formate.

$$\underset{\text{Calcium formate.}}{Ca(CHO_2)_2} + \underset{\text{Calcium butyrate.}}{Ca(C_4H_8O_2)_2} =$$
$$\underset{\text{Calcium carbonate.}}{2CaCO_3} + \underset{\text{Butyric aldehyde.}}{2C_4H_8OH.}$$



Formaldehyde, $CH_2OH = C\begin{matrix} =O \\ -H \\ \backslash H \end{matrix}$, is produced by the dry distillation of calcium formate, or by the oxidation of methyl alcohol. It is a gas at ordinary temperatures, and on standing it is gradually polymerized into paraformaldehyde, $C_3H_9O_3 = 3(CH_2OH)$, a crystalline solid. Formaldehyde, as a 40 per cent. solution in water, has been introduced into the market under the name of **formalin.** It is used as an antiseptic and food preservative.

Acetic Aldehyde--Aldehyde, C_2H_4O—is prepared on a large scale in the manufacture of alcohol, when it distils over with the first of the distillate. Commercial alcohol generally contains traces of aldehyde.

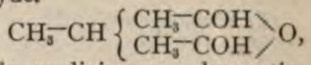
It may be prepared by distilling from a retort, a mixture of three parts of crystals of potassium dichromate, four parts of sulphuric acid, twelve parts of water, and four parts of alcohol. The receiver must be placed in a freezing mixture. Manganese dioxide may be used instead of the dichromate.

The impure aldehyde thus obtained is treated with dry calcium chloride to remove water, and then mixed with twice its volume of ether, surrounded by a freezing mixture, and saturated with dry ammonia gas. The crystalline aldehyde-ammonia thus formed, is separated and distilled with diluted sulphuric acid from a flask or retort, connected with a well-cooled receiver. It may then be freed from water by standing over fused calcium chloride and redistilling.

Aldehyde is a colorless, transparent, mobile liquid, boiling at 21° C. (69.8° F.). It has an acrid, suffocating odor, irritating the eyes. It mixes in all proportions with water, alcohol, and ether.

It acts as a strong reducing agent. If mixed with a solution of ammoniated silver nitrate, and warmed, the silver is reduced, and deposited upon the glass in the form of a mirror. It gives the general reactions of the aldehydes. A general test for the aldehydes is their property of restoring the red color of a solution of fuchsine which has been decolorized with sulphurous acid.

The vapor of aldehyde, when inhaled, produces asphyxia. When taken internally it produces intoxication. When pure aldehyde is left for some time in contact with HCl, SO_2, $COCl_2$, or $ZnCl_2$, it undergoes a change, forming two polymeric compounds known as paraldehyde and metaldehyde.

Paraldehyde, $(C_2H_3OH)_3$ or 

$$CH_3{-}CH\left\{\begin{array}{l}CH_3{-}COH\\CH_3{-}COH\end{array}\right\rangle O,$$

Paraldehydum, U. S. P., is used in medicine as a hypnotic. It is prepared by treating aldehyde with a very small quantity of HCl or with $ZnCl_2$. The temperature of the liquid rises, and almost complete conversion into paraldehyde takes place. Purification is effected by freezing out and rectifying. Paraldehyde is a clear, colorless liquid, with an ethereal odor, and a burning, afterward cooling, taste. Specific gravity, 0.998. Boils at 124° C. (255.2° F.), and congeals to a crystalline mass at 10° C. (50° F.). One part dissolves in ten of water, forming a neutral solution, miscible in all proportions with alcohol and ether. $BaCl_2$ and $AgNO_3$ solutions should give no precipitate with it (absence of sulphates and chlorides), and it should give no coloration after two hours' contact with a solution of KOH or NaOH (absence of aldehyde). It may be given in doses of 20 to 40 minims.

Metaldehyde $(C_2H_4O)_n$, is formed from aldehyde by H_2SO_4 or HCl gas at a temperature below 0° C. (32° F.). It is a white, crystalline solid, occurring in needles or prisms. When heated, it sublimes without melting at 112° to 115° C. (234° to 239° F.). It is insoluble in water, but soluble in hot alcohol and ether.

It also has been used as a hypnotic.

Sulphaldehyde, C_2H_3SH, is prepared by the action of H_2S upon aldehyde. It is an oily liquid with a disagreeable odor. When treated with acids it polymerizes like aldehyde, producing a solid thio-paraldehyde, giving physiological effects like those of paraldehyde.

Of the large number of aldehydes known, a few occur in natural products of vegetable origin.

Benzoic Aldehyde, C_6H_5COH, occurs in **oil of bitter almonds.** It is prepared in the fruit by the decomposition of the glucoside, **amygdalin,** by the **ferment emulsin.** It is a colorless or pale yellow, oily liquid with a characteristic odor. It is prepared artificially from toluene.

Cinnamic Aldehyde, C_8H_7COH, occurs in the oils of cinnamon and cassia. When oxidized it gives cinnamic acid.

Salicylic Aldehyde, $C_6H_5O.COH$, or oil of spiræa (meadow sweet), is prepared from salicin by distilling with H_2SO_4 and $K_2Cr_2O_7$.

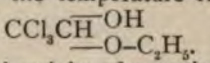
Cuminic Aldehyde occurs in the oils of cumin, caraway, etc.

Vanillic Aldehyde, or **Vanillin,** $C_7H_7O_2.COH$, is extracted from the vanilla bean pods. It is now made artificially from **coniferin,** a glucoside obtained from the pine family.

Trichlor-aldehyde, or **Chloral,** $CCl_3{-}COH$, is aldehyde in which the three hydrogen atoms of the radical have been replaced by the chlorine atoms; thus: C_2H_3OH. C_2Cl_3OH. It is prepared by passing dry chlorine into absolute alcohol until it is saturated. The liquid separates into two layers. The lower layer is separated and shaken several times with H_2SO_4, and finally distilled from the acid. It is thus obtained as a colorless, oily liquid, having a pungent, irritating odor and a bitter, acrid, caustic taste. It boils at 94.5° C. (202° F.); sp. gr. 1.502. It is very soluble in water, alcohol, and ether. It dissolves the halogens, sulphur, and phosphorus. It answers to all the general tests of the aldehydes mentioned above. Oxidizing agents convert it into **trichlor-acetic acid,** C_2Cl_3OOH, a colorless, crystalline solid, soluble in water. Trichlor-acetic acid has been used as a delicate test for albumin in the urine. Chloral is converted into chloroform and a formate by the alkaline hydroxides.

$$C_2Cl_3OH + NaOH = NaCHO_2 + CHCl_3.$$

This reaction is employed to prepare a very pure chloroform for anæsthetic purposes. It unites with water to form **chloral hydrate,** $C_2Cl_3OH.H_2O$ (chloral, U. S. P.), a colorless, transparent, crystalline solid, having a pungent odor and an acrid taste. It volatilizes slowly at ordinary temperatures, fuses at 57° C. (134.6° F.), and boils at 98° C. (208° F.), with partial decomposition into water and chloral. Chloral hydrate is readily soluble in water. Under the influence of sunlight, potassium chlorate decomposes chloral with violence

Chloral combines with a considerable range of organic substances. When dissolved in alcohol the temperature rises, and **chloral alcoholate** crystallizes out,  $CCl_3CH\begin{matrix}OH\\ -O-C_2H_5\end{matrix}$. Chloral liquefies when triturated with an equal weight of camphor, menthol, thymol or phenol.

Action on the Economy.—It has been claimed that the action of chloral on the economy is due to the formation of chloroform and a formate, by decomposition after absorption, or in the intestine. Such is probably not the case.

When taken in an overdose, chloral acts as a poison, 30 grains having proved fatal, although five or six times that amount has been taken by others with no bad effect. The symptoms of poisoning by chloral are not uniform or very characteristic. Strychnine has been recommended as a physiological antidote. The stomach should be emptied, and stimulants given freely. Death is likely to occur from heart depression.

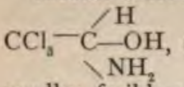
Tests.—Chloral may be detected in the contents of the stomach by rendering them alkaline with KOH, heating on a water bath, and conducting the vapors through a red-hot tube, and then allowing them to bubble through a solution of $AgNO_3$. If chloral is present it decomposes, giving off chloroform, which is decomposed, in passing through the hot tube, into HCl and free chlorine. The HCl gives a white precipitate of AgCl. The same experiment without the addition of KOH, if it gave positive results, would prove the presence of chloroform, and not chloral, in the contents of the stomach. If the use of chloral hydrate be long continued, it induces a **chloral habit.**

Croton Chloral, or **Butyl-Chloral,** $C_3H_4Cl_3COH$, bears the same relation to butyl alcohol that chloral does to ethyl alcohol.

C_2H_5OH Ethyl alcohol.	C_2H_3OH Aldehyde.	C_2Cl_3OH Chloral.
C_4H_9OH Butyl alcohol.	C_4H_7OH Butyl aldehyde.	$C_4H_4Cl_3OH$ Tri-chlor butyl aldehyde, or Croton chloral.

It is prepared by substituting aldehyde for alcohol in the preparation of chloral.

It is an oily liquid of pungent odor, boiling at 164° C. (327.2° F.). It combines with water to form **croton chloral hydrate,** a crystalline solid, used in medicine as a hypnotic.

Chloral combines with ammonia to form **chloral-ammonia**  $CCl_3{-}\overset{\diagup H}{\underset{\diagdown NH_2}{C}}{-}OH$, a white, crystalline powder, consisting of fine needles, fusible at 62° to 64° C. (143.6° to 147.2° F.), soluble in water, and easily decomposing when in solution. It has been used as a hypnotic in doses of 15 to 30 grains.

Chloral shows a readiness to combine with the compound ammonias, amids, and camphors. **Chloral-ammonium (chloral-amid), chloral-formamid, chloral-imid, chloral-menthol, chloral-urethan,** and a number of like compounds, or mixtures, have been introduced and advocated as remedies for various purposes. Most of these are mentioned elsewhere.

Hypnal is a crystalline body formed by the action, at ordinary temperatures, of chloral hydrate upon antipyrin in solution. It is a tasteless, odorless body, soluble in 5 or 6 parts of water.

It is used as a hypnotic and anodyne.

Chloral-oximes are a class of bodies formed by the reaction of hydroxylamin with aldehydes and ketones, and have recently been recommended as hypnotics. The following chloral-oximes have been prepared: **Chloral-acetoxime,** $CCl_3COH_2.ON\begin{cases}CH_3\\CH_3\end{cases}$; **Chloral-acetaldoxime**, $CH_3CH = NOCH(OH)CCl_3$; **Chloral-benzaldoxime,** $C_6H_5CH = NOCH(OH)CCl_3$; **Chloral-Camphoroxime,** $C_{10}H_{16} = NOCH(OH)CCl_3$. All these oximes are crystalline compounds easily soluble in alcohol and ether, and are decomposed by hot water.

Chloralose or **Anhydrogluco-chloral,** $C_6H_{11}C_3O_6$, is the name given to a compound formed by heating chloral and glucose for one hour at 100° C. (212° F.).

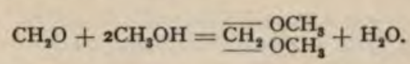
$$CCl_3COH + C_6H_{12}O_6 = C_8H_{11}Cl_3O_6 + H_2O.$$

It forms fine colorless needles, melting at 184° C. (363° F.). It is soluble in 170 parts of water at 15° C. (59° F.), readily soluble in alcohol and ether. It has a bitter taste. It has been recommended as a substitute for chloral, and is claimed to be free from the unpleasant after-effects of chloral upon the heart.

ACETALS.

The acetals are formed by the union of alcohol with aldehydes, with the elimination of water, or by the oxidation of the alcohols, when the aldehyde reacts upon part of the alcohol.

Methylal, $CH_2\left\langle\begin{matrix}OCH_3\\OCH_3\end{matrix}\right.$, is obtained by oxidizing methyl alcohol with sulphuric acid and manganese dioxide, distilling the mixture and collecting that portion coming over between 40° C. and 50° C. (104° F. and 122° F.). The product is redistilled and freed from water by standing in contact with dry K_2CO_3. The reaction is first to oxidize the methyl alcohol to formaldehyde, which reacts upon more CH_3OH.

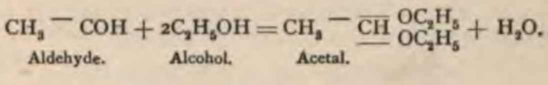


$$CH_2O + 2CH_3OH = \overline{\underline{CH_2}}\begin{matrix}OCH_3\\OCH_3\end{matrix} + H_2O.$$

Methylal is a colorless, mobile liquid, with a penetrating ethereal odor, and boiling at 42° C. (107.6° F.). It is soluble in 13 parts of water, and in alcohol, ether, fixed and volatile oils. It should not decolorize potassium permanganate solutions acidified with sulphuric acid. Strong H_2SO_4 decomposes it, but alkalies do not.

It has been used as a hypnotic, and as a cerebral sedative.

Acetal, $CH_3CH\left\langle\begin{matrix}OC_2H_5\\OC_2H_5\end{matrix}\right.$, is formed when acetic aldehyde is heated with alcohol for some time.



$$\underset{\text{Aldehyde.}}{CH_3 - COH} + \underset{\text{Alcohol.}}{2C_2H_5OH} = \underset{\text{Acetal.}}{CH_3 - \overline{\underline{CH}}\begin{matrix}OC_2H_5\\OC_2H_5\end{matrix}} + H_2O.$$

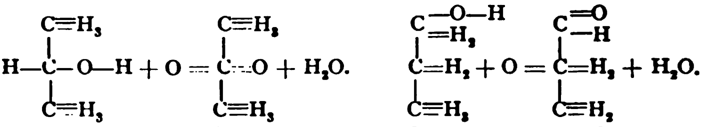
It is also found in raw grain spirit.

It is a colorless liquid of agreeable taste boiling at 104° C. (219° F.).

KETONES.

These bodies are the first result of the oxidation of secondary alcohols, *i. e.*, upon an alcohol that contains the group $C\begin{matrix}-H\\O-H\end{matrix}$ instead of $C\begin{matrix}/\!\!/H_2\\O-H\end{matrix}$, as in the primary alcohol.

The ketones all contain the group CO. The relation of these bodies will be made clear by the following graphic formulæ:—



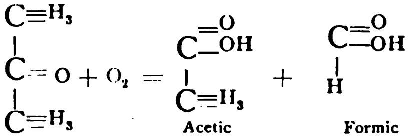
$$\begin{array}{c} C{\equiv}H_3 \\ | \\ H{-}C{-}O{-}H \\ | \\ C{\equiv}H_3 \end{array} + O = \begin{array}{c} C{\equiv}H_3 \\ | \\ C{=}O \\ | \\ C{\equiv}H_3 \end{array} + H_2O. \qquad \begin{array}{c} C{-}O{-}H \\ {=}H_2 \\ | \\ C{=}H_2 \\ | \\ C{\equiv}H_3 \end{array} + O = \begin{array}{c} C{=}O \\ {-}H \\ | \\ C{=}H_2 \\ | \\ C{\equiv}H_3 \end{array} + H_2O.$$

Isopropyl alcohol. Di-methyl ketone, or acetone. Propyl alcohol. Propyl, aldehyde.

In the nomenclature of the ketones, the name is made to contain the names of all the radicals attached to the CO″ group. Thus, **ethyl-methyl-ketone** would express the name of the following: $CH_3{-}CH_2{-}CO{-}CH_3$.

Ketones are distinguished from aldehydes by their behavior with reagents.

Nascent hydrogen regenerates the secondary alcohol with ketones, and a primary alcohol with aldehydes. Oxidation produces with aldehydes the corresponding acid, while the oxidation of ketones splits the molecules with the formation of two acids.



$$\begin{array}{c} C{\equiv}H_3 \\ | \\ C{=}O \\ | \\ C{\equiv}H_3 \end{array} + O_2 = \begin{array}{c} C{=}O \\ {-}OH \\ | \\ C{\equiv}H_3 \end{array} + \begin{array}{c} C{=}O \\ {-}OH \\ | \\ H \end{array}$$

Acetone. Acetic acid. Formic acid.

Acetone—Acetyl-methylid—Di-methyl Ketone $(CH_3)_2CO$—is formed by the dry distillation of the acetates, sugar, tartaric acid, and by a number of other reactions. It is usually obtained by the distillation of calcium acetate.

$$\underset{\text{Calcium acetate.}}{2Ca(C_2H_3O_2)_2} = \underset{\text{Acetone.}}{2(CH_3)_2CO} + \underset{\text{Calcium carbonate.}}{2CaCO_3}.$$

It may be prepared by passing the vapor of a 60 per cent. acetic acid through a rotating tubular still, containing pumice stone or barium carbonate, heated to a dull red heat (Squibb).

$$2HC_2H_3O_2 = C_3H_6O + CO_2 + H_2O.$$

Acetone is present in very small quantities in normal urine and blood, but in larger quantities in diabetes mellitus and in acetonuria. It is a transparent, colorless liquid, having a peculiar ethereal odor. It is miscible with alcohol and ether. It is miscible in water, but separates on the addition of salts. It shows the aldehyde reaction with fuchsine and sulphurous acid. It is a good solvent for resins, fats, camphor, gun cotton, etc. It is used as a solvent in varnish manufacture. Its specific gravity is 0.7966. It boils at 56° C. (132.8° F.). Chlorine or bromine, in presence of alkalies, convert it into chloroform or bromoform, and is employed for the preparation of chloroform.

Sulphur Derivatives of the Hydrocarbons and Alcohols.—As we have seen in inorganic chemistry, sulphur can replace oxygen in many compounds, especially where it acts as a linking atom. Thus corresponding to H_2O we have H_2S; to NH_4OH, NH_4SH; to H_2CO_3, H_2CS_3. So in alcohols we may have sulphur take the place of oxygen. These compounds are frequently called Mercaptans (mercuro captum) from their property of readily taking up mercury. They may be more properly named sulpho-alcohols or thio-alcohols. In the ethers and aldehydes we may have the same substitution of sulphur for oxygen, giving rise to sulphides of the hydrocarbon radicals or sulphaldehydes. These compounds, as a class, are generally ill-smelling compounds, and are frequently produced in the putrefactive fermentation of organic substances containing sulphur. The following is a list of some of the more important of this class of compounds:—

SULPHIDES OF THE HYDROCARBON RADICALS.

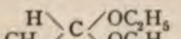
Methyl sulphide, $(CH_3)_2S$
  " disulphide, $(CH_3)_2S_2$
  " trisulphide, $(CH_3)_2S_3$
  " hydrosulphide, CH_3SH (methyl mercaptan)
Ethyl hydrosulphide, C_2H_5SH (mercaptan)
Ethyl oxysulphide, $(C_2H_5)_2SO$
Ethyl sulphonic acid, $C_2H_5SO_2OH$
Diethyl disulphide, $(C_2H_5)_2S_2$
  " trisulphide, $(C_2H_5)_2S_3$
  " tetrasulphide, $(C_2H_5)_2S_4$
  " pentasulphide, $(C_2H_5)_2S_5$
  " di-ethyl oxysulphide, $(C_2H_5)_2SO_2$ (ethyl sulphone)
Xanthic acid, C_2H_5OCSSH
Diethyl sulpho-dimethyl-methane, or sulphonal, $(CH_3)_2C(SO_2C_2H_5)_2$.

Of these compounds but few have sufficient importance to claim our attention. Compounds similar to the foregoing may be formed by other radicals than those here mentioned.

Ethyl Mercaptan, C_2H_5SH, is prepared by distilling calcium sulph-ethylate with potassium hydro-sulphide.

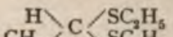
$$\underset{\text{Calcium sulphethylate.}}{Ca(C_2H_5SO_4)_2} + 2KHS = CaSO_4 + K_2SO_4 + \underset{\text{Mercaptan.}}{2(C_2H_5SH)}.$$

Mercaptan forms the upper layer of the distillate. Mercaptan has a powerful smell of garlic. It is a volatile liquid; sp. gr. 0.835. It burns with a blue flame. It is sparingly soluble in water, and dissolves in alcohol and ether. It forms, with metallic sodium and potassium, sodium mercaptid, C_2H_5SNa, which is a crystalline compound soluble in water. Mercuric oxide reacts with mercaptan, evolving heat and forming a crystalline, inodorous compound, **mercuric mercaptid.** When a mixture of 2 molecule of mercaptan with 1 molecules of an aldehyde is treated with dry HCl, a **mercaptal** is produced which may be regarded as an acetal whose oxygen is replaced by sulphur. If this same reaction is produced with an acetone in place of an aldehyde, a **mercaptol** is produced, which differs from the mercaptal in that the alcoholic radical is substituted for the remaining H atom of the methane. The relation of these bodies may be seen by reference to the following graphic formulæ:—



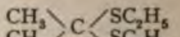
$\begin{matrix} H \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} OC_2H_5 \\ OC_2H_5 \end{matrix}$

Acetal.



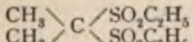
$\begin{matrix} H \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} SC_2H_5 \\ SC_2H_5 \end{matrix}$

Mercaptal.



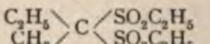
$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} SC_2H_5 \\ SC_2H_5. \end{matrix}$

Mercaptol.



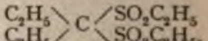
$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} SO_2C_2H_5 \\ SO_2C_2H_5 \end{matrix}$

Sulphonal.



$\begin{matrix} C_2H_5 \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} SO_2C_2H_5 \\ SO_2C_2H_5 \end{matrix}$

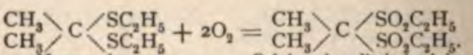
Trional.



$\begin{matrix} C_2H_5 \\ C_2H_5 \end{matrix}\!>C<\!\begin{matrix} SO_2C_2H_5 \\ SO_2C_2H_5. \end{matrix}$

Tetronal.

Ethyl mercaptol, $(CH_3)_2C(SC_2H_5)_2$, is produced by the action of dry HCl upon a mixture of acetone and mercaptan, or upon a mixture of sodium-ethyl thio-sulphate and acetone. The liquid gradually becomes turbid and separates into two layers, of which the upper is mercaptol, the lower dilute HCl. Mercaptol is a mobile liquid whose odor is not disagreeable. It boils at 80° C. (176° F.). When mercaptol is oxidized by potassium permanganate, it is converted into **sulphonal** or diethyl sulphon-dimethyl-methane, according to the following equation:—



$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} SC_2H_5 \\ SC_2H_5 \end{matrix} + 2O_2 = \begin{matrix} CH_3 \\ CH_3 \end{matrix}\!>C<\!\begin{matrix} SO_2C_2H_5 \\ SO_2C_2H_5. \end{matrix}$$

Mercaptol. Sulphonal or diethyl-sulphon-dimethyl-methane.

Sulphonal is a colorless, inodorous, practically tasteless, crystalline body, melting at 125° C. (257° F.). It is soluble in 15 parts of boiling water and in about 450 of cold. It is freely soluble in hot alcohol and less so in cold. Sulphonal is a very stable body, being unaffected by acids, alkalies, oxidizing agents, bromine, or chlorine. Owing to its insolubility and stability, it does not present many characteristic reactions. Its solutions are neutral to test paper, and are unaffected by barium nitrate or silver nitrate. It should burn away without residue when ignited with free access to air. When sulphonal is heated with potassium cyanide, the odor of mercaptan is evolved, and when the residue is dissolved in water, a drop of Fe_2Cl_6 gives a red color to the solution. The urine of patients taking considerable doses of sulphonal assumes a peculiar reddish-brown color, due to the presence of hæmatoporphyrin. This substance is most easily detected by the spectroscope. Sulphonal is used in medicine as a hypnotic, and has become official in the pharmacopœias of several European countries. By oxidation of ethyl mercaptan, **ethyl sulphonic acid** is formed.

$$\underset{\text{Ethyl mercaptan.}}{2C_2H_5SH} + 3O_2 = \underset{\text{Ethyl sulphonic acid.}}{2C_2H_5SO_2OH.}$$

Sulphonic acids may be formed by acting directly upon unsaturated hydrocarbons with sulphuric acid.

$$\underset{\text{Sulphuric acid.}}{H_2SO_4} + \underset{\text{Benzene.}}{C_6H_6} = \underset{\text{Benzene sulphonic acid.}}{C_6H_5SO_2OH} + \underset{\text{Water.}}{H_2O.}$$

$$H_2SO_4 + \underset{\text{Toluene.}}{C_6H_5CH_3} = \underset{\text{Toluene sulphonic acid.}}{C_6H_4CH_3SO_2OH} + H_2O.$$

It will be seen by the above reactions that sulphonic acids correspond with the sulphites.

Ortho-phenol sulphonic acid—sozolic acid—or **aseptol,** $C_6H_4 \left\{ \begin{matrix} OH \\ SO_2OH, \end{matrix} \right.$ is sometimes employed as a non-poisonous, non-irritating antiseptic. It occurs sometimes in small, deliquescent needles, but generally appears in the form of a heavy, red liquid of a syrupy consistency. It has an astringent taste and an odor resembling that of phenol. It is freely soluble in water, alcohol, and glycerin. It has been employed as an antiseptic, both internally and externally.

A calcium salt of beta-naphthol sulphonate has recently been introduced as an antiseptic under the name of **asaprol,** $Ca(C_{10}H_6SO_2OH)_2$. It occurs in acicular crystals, readily soluble in water and alcohol. It has been used internally in doses of from 15 to 60 grs.

Alumnol, β-Naphtol-disulphonate of Aluminum, $(C_{10}H_5(OH)(SO_3)_2)_3Al_2$, is a colorless powder, easily soluble in water and glycerin. It darkens on exposure to air.

It is prepared by heating β-naphtol with H_2SO_4 at 110° C. (230° F.). The resulting naphtol-disulphonic acid is converted into the barium salt, and this treated with aluminum sulphate to produce the aluminum salt.

It is used as an antiseptic and astringent. Aromatic sulphonic acids will be found on page 439.

Saccharin, or **benzoil-sulphonic imid,** $C_6H_4COSO_2NH$, has been introduced as a sweetening agent. Its sweetening power is 200 to 300 times that of sugar. The substance is usually prepared from toluene sulphonic acid. It is a white powder, with an intense sweet taste and a fine almond odor. It is slightly soluble in water, forming a feebly acid liquid. It is more soluble in alcohol, glycerin, ammonia water, or in a solution of sodium bicarbonate. Saccharin has been largely recommended as a sweetening agent for use by diabetics, to avoid the use of sugar. It has, however, proven unsuitable for this purpose, owing to its disturbing effects upon the digestion. Owing to these effects, also, its use has been prohibited by statute in several European countries. It is sometimes employed to sweeten wines. It is sometimes used in pharmacy to sweeten elixirs, syrups, etc., and to correct the taste of the alkaloids and bitter principles.

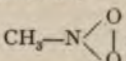
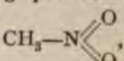
Ichthyol is a sodium salt of a complex sulphonic acid, having the empirical formula $C_{28}H_{36}S_3O_6(NH_4)_2$. It is obtained by the distillation and purification of a pitch-like mineral deposit. It is a dark-brown, pitch-like mass, having a disagreeable, tarry odor.

Organo-metallic Compounds.—The hydrocarbon radicals can be made to combine with certain metals. They are usually obtained by the action of the iodide of an alcoholic radical upon the metallic element in an atmosphere of H. They are substances which have been put to no use in the arts or in medicine, but are of interest principally in chemical synthesis. The hydrocarbon radicals also combine with ammonia, phosphine, arsine, and stibine. These compounds are similar to the ammonium compounds, which we shall study later. They are of no therapeutic interest.

The Nitro Derivatives of the Hydrocarbons.—These are colorless liquids of ethereal odor, usually insoluble in water. They distil without decomposition, and sometimes explode on being quickly heated. They are distinguished from the ethers by not being saponified and by yielding amins on reduction; the N not being separated from the hydrocarbon radical. Thus:

$$\underset{\text{Nitro methane.}}{CH_3NO_2} + 3H_2 = \underset{\text{Methyl amin.}}{CH_3NH_2} + 2H_2O.$$

These nitro-compounds may be formed by treating the iodide of the hydrocarbon radical with silver nitrate, or, in some cases, by the direct action of nitric acid upon the hydrocarbon. This reaction, however, seldom takes place with the paraffins.

The constitution of the nitro compounds is distinguished from the ethers in not being saponifiable, and from the fact that the nitrogen is not split off in their reduction, but remain bound to the carbon. From this we conclude that the nitrogen in them must be directly joined to the carbon, and not linked to it by oxygen, as in the case of nitrous ethers. The graphic formula of nitro methane must be considered to be  $CH_3-N\begin{smallmatrix}O\\|\\O\end{smallmatrix}$ or  $CH_3-N\begin{smallmatrix}=O\\=O\end{smallmatrix}$, while nitrous ether must be considered to be $CH_3-O-N=O$.

The nitro-paraffins are not so numerous or important as those of the benzene or aromatic compounds, which will be considered later.

Nitrils, or Cyanides of Hydrocarbon Radicals.—Hydrocyanic acid yields two classes of derivatives by the exchange of its H atom for alcohol radicals, neither of which can be grouped among the ethers, since they do not go back into alcohols and hydrocyanic acid upon saponification, but decompose in another direction. These two classes of compounds are known as nitrils and iso nitrils.

The nitrils are either colorless liquids which volatilize without decomposition, or solids of ethereal odor, lighter than air and relatively stable. They boil at about the same temperature as the corresponding alcohols. They are formed by heating the iodide of the radical with potassium cyanide, or by heating potassium ethyl-sulphate with potassium cyanide.

$$CH_3I + KCN = KI + \underset{\text{Methyl cyanide.}}{CH_3CN}$$

$$\underset{\substack{\text{Potassium ethyl}\\ \text{sulphate.}}}{\left.\begin{matrix}KO\\ C_2H_5O\end{matrix}\right\} SO_2} + \underset{\substack{\text{Potassium}\\ \text{cyanide.}}}{KCN} = \underset{\substack{\text{Ethyl}\\ \text{cyanide.}}}{C_2H_5CN} + \underset{\substack{\text{Potassium}\\ \text{sulphate.}}}{K_2SO_4}$$

They may also be prepared by the dehydration of the ammonia salts of the corresponding acid, by means of P_2O_5,

$$\underset{\substack{\text{Ammonium}\\ \text{acetate.}}}{C_2H_3O_2NH_4} = \underset{\substack{\text{Methyl cyanide, or}\\ \text{aceto-nitril.}}}{CH_3CN + 2H_2O} \qquad \underset{\text{Acetamid.}}{C_2H_3ONH_2} = \underset{\substack{\text{Methyl cyanide, or}\\ \text{aceto nitril.}}}{CH_3CN + H_2O}$$

or by distilling the ammonium salts of mono-basic acids, which contain one atom of carbon more than the alcohol which would correspond to the nitril desired. $C_2H_3O_2NH_4 = CH_3CN + 2H_2O$. As a consequence of these modes of formation, these compounds are termed the nitrils of the monobasic acids, that is, CH_3CN is named aceto-nitril; C_2H_5CN, propio nitril, or ethyl cyanide. When these compounds are heated with acids, alkalies, or superheated steam, they break up into the acids from which they were originally prepared, and ammonia. Nascent H converts them into amins (see aceto-nitril, methyl cyanide). CH_3CN is present in the products of the distillation of coal tar. It is a colorless liquid, boiling at 82° C. (179° F.), is combustible, and miscible with water. The other nitrils of the higher hydrocarbon radicals are only of theoretical interest. Cyanides of the other series of hydrocarbons also exist.

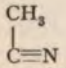
Fulminate of Mercury ($Hg(CN_2)O_2$) is obtained by warming alcohol with nitric acid and mercuric nitrate. It crystallizes in fine, silky prisms, which explode with great violence on being heated or struck. Fulminate of silver, having a similar composition, is even more explosive. These fulminating compounds are used in the manufacture of percussion caps.

The iso-cyanides, or iso-nitrils, or carbamins, are colorless liquids, easily soluble in alcohol and ether, but slightly soluble, or insoluble, in water. They have a feeble alkaline reaction, disagreeable odor, and poisonous properties. They are prepared by heating the iodides of the alcohol radicals with silver cyanide instead of potassium cyanide.

$$CNAg + C_2H_5I = AgI + \underset{\text{Ethyl iso-cyanide.}}{C_2H_5NC}$$

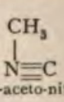
They may also be formed by the action of chloroform and an alcoholic solution of KOH, upon the primary amins. The iso-nitrils differ from the nitrils by their behavior with water or dilute acids. When superheated with water or with acids in the cold, they split up into formic acid and an amin base. They do not decompose with alkalies as nitrils do. Aceto iso-nitril has the composition CH_3NC, while aceto-nitril has the composition CH_3CN, *i. e.*, the N and not the C is tied to the CH_3 group in the iso-nitril. The iso-nitrils, therefore, are generally distinguished from the nitrils by reversing the positions of the C and N.

The following graphic formulæ will make this distinction clear:—



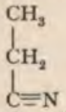
$CH_3-C\equiv N$

Aceto-nitril.



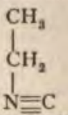
$CH_3-N\equiv C$

Iso-aceto-nitril.



$CH_3-CH_2-C\equiv N$

Propio-nitril.



$CH_3-CH_2-N\equiv C$

Iso propio-nitril.

In most cases the cyanides of the hydrocarbon radicals—nitrils—can be converted into acids by heating them with KOH, HCl, or with H_2SO_4, diluted with its own volume of water, thus:—

$$CH_3CN + 2H_2O = CH_3COOH + NH_3.$$

The relation of the derivatives of the various substitution products of the hydrocarbons may be illustrated by the following formulæ, derived from the first two members of the paraffin eries:—

Hydrocarbon.	Methane, $C\equiv H_4$.	Ethane $C\equiv H_3C\equiv H_3$.
Haloid Ether.	Methyl Chloride, $C\equiv H_3Cl$.	Ethyl Chloride, $C\equiv H_3C=H_2Cl$.
Monohydric Alcohol.	Methyl Alcohol, $C\equiv H_3OH$.	Ethyl Alcohol, $C\equiv HC=H_2OH$.
Dihydric Alcohol.		Ethylene Glycol or Glycol. $C\equiv H_3C\overline{H}O_2H_2$.
Ether or Oxide.	Methyl Ether, $\left.\begin{matrix}CH_3\\CH_3\end{matrix}\right\}O$.	Ethyl Ether, $\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$.
Compound Ether.	Methyl Nitrite, $CH_3{-}O{-}N{=}O$.	Ethyl Acetate, $C_2H_5{-}O{-}C_2H_3O$.
Aldehyde.	Formaldehyde, $C\begin{matrix}=H_2\\=O\end{matrix}$.	Ethyl Aldehyde, $C\equiv H_3C\begin{matrix}=O\\-H\end{matrix}$.
Ketone or Acetone.		Can exist only with three carbon atoms. Acetone, $C\equiv H_3CO-C\equiv H_3$.
Acetal.	Methylal, $CH_2\begin{matrix}-OCH_3\\-OCH_3\end{matrix}$.	Acetal, $C\equiv H_2\begin{matrix}O-C_2H_5\\O-C_2H_5\end{matrix}$
Nitril.	Methyl Cyanide, $C\equiv H_3C\equiv N$.	Ethyl Cyanide, $C_2H_5-C\equiv N$.
Monobasic Acid.	Formic Acid, $C\begin{matrix}=O\\-H\end{matrix}OH$.	Acetic Acid, $C\equiv H_3C\begin{matrix}=O\\-OH\end{matrix}$.
Dibasic Acid.		Oxalic Acid, $\begin{matrix}CO.O-H\\ \vert\\ CO.O-H.\end{matrix}$

ORGANIC ACIDS.

The characteristic feature of an organic acid molecule is that it must contain the carboxyl group—COOH. The basicity of the acid will depend upon the number of these groups contained in its molecule. The organic acids partake of the general properties of the inorganic acids. They may be referred to the water type, and be considered as one or more molecules of water, in which one-half the hydrogen has been replaced by an organic compound radical containing oxygen—a negative radical—while the remaining hydrogen remains as replaceable or basic hydrogen.

$H{-}O{-}H$.	$H{-}O{-}C_2H_3O$.	$\left.\begin{matrix}H{-}O{-}\\H{-}O{-}\end{matrix}\right\}C_4H_4O_4$
Water.	Acetic acid.	Tartaric acid.

As in inorganic acids, only those hydrogen atoms which are linked to the radical by oxygen are replaceable by a metal or basic radical. Organic acids may be formed by the oxidation of primary alcohols or aldehydes. The presence of an alkali favors the formation of an acid by oxidation.

Acids may be **monobasic, dibasic, tribasic,** etc., according as their molecules contain one, two, three, etc., carboxyl groups, (—COOH). Acids may also contain one or more hydroxyl groups, (OH), which are not basic, because not immediately attached to or associated with CO, to form the carboxyl group. The hydrogen of these hydroxyl groups is called **alcoholic hydrogen,** to distinguish it from the other replaceable hydrogen, designated as **basic.** The number of hydroxyl groups in a molecule of either an alcohol or an acid is said to be its **atomicity.** It is evident that the atomicity of an acid may be greater than its basicity, when it is said to be an alcohol acid.

Lactic Acid, $(H\text{-}O\text{—}COCH(OH)CH_3 = \left(C_3H_4O\left\{\begin{matrix}OH\\OH\end{matrix}\right.\right)$, is a good example of a diatomic and monobasic acid.

The number of organic acids known is very large; only a few of the most prominent ones can, therefore, be mentioned here.

Of the many series of acids, the most numerous and important are those of the **acetic** or **fatty acid** series, corresponding to the marsh gas series of hydrocarbons.

The acids of this series are obtained by the oxidation of the corresponding alcohols or aldehydes.

$$\underset{\text{Alcohol.}}{C_2H_5\text{—}O\text{—}H} + O_2 = \underset{\text{Acetic acid.}}{C_2H_3O\text{—}O\text{—}H} + H_2O.$$

$$\underset{\text{Aldehyde.}}{2C_2H_3OH} + O_2 = \underset{\text{Acetic acid.}}{2C_2H_3O\text{—}O\text{—}H}.$$

They may also be obtained by the action of the alkaline hydroxides upon the cyanides of the radical of the next lower alcohol.

$$CH_3CN + KOH + H_2O = NH_3 + KC_2H_3O_2.$$

A few have been obtained by synthesis from carbon monoxide.

$$CO + KOH = \underset{\text{Potass. formate.}}{CHO\text{—}O\text{—}K}.$$

THE FATTY ACIDS, OR ALOPHATIC ACIDS.

The following is a list of the principal members of the fatty acid series, general formula $C_nH_{2n+1}COOH$. They are all saturated acids, *i. e.*, formed from saturated hydrocarbons.

		Fusing Point.	Boiling Point.	Occurrence.
Formic acid,	$CHOOH$,	4° C.	100° C.	Red ants, nettles.
Acetic acid,	CH_3COOH,	17° C.	118° C.	Vinegar.
Propionic acid,	C_2H_5COOH,	-21° C.	140° C.	Sweat, oxidation of oils.
Butyric acid,	C_3H_7COOH,	-20° C.	162° C.	Rancid butter.
Valerianic acid,	C_4H_9COOH,	-16° C.	185° C.	Valerian root.
Caproic acid,	$C_5H_{11}COOH$,	- 2° C.	205° C.	Rancid butter.
Œnanthylic acid,	$C_6H_{13}COOH$,	-10° C.	224° C.	Oxidation of castor oil.
Caprylic acid,	$C_7H_{15}COOH$,	14° C.	236° C.	Rancid butter, cocoanut oil.
Pelargonic acid,	$C_8H_{17}COOH$,	18° C.	254° C.	Geranium leaves.
Capric acid,	$C_9H_{19}COOH$,	30° C.	270° C.	Butter.
Lauric acid,	$C_{12}H_{23}COOH$,	43° C.	. . .	Bay berries.
Myristic acid,	$C_{13}H_{27}COOH$,	54° C.	. . .	Cocoanut oil, nutmeg, butter.
Palmitic acid,	$C_{15}H_{31}COOH$,	62° C.	. . .	Palmitic acid, palm oil, animal fats.
Margaric acid,	$C_{16}H_{33}COOH$,	60° C.	. . .	Synthesis.
Stearic acid,	$C_{17}H_{35}COOH$,	70° C.	. . .	Most solid animal fats.
Arachidic acid,	$C_{19}H_{39}COOH$,	75° C	. . .	Certain vegetable oils.
Behenic acid,	$C_{21}H_{43}COOH$,	76° C.	. . .	" " "
Hyænic acid,	$C_{24}H_{49}COOH$,	77° C.	. . .	Fat of hyæna.
Cerotic acid,	$C_{26}H_{53}COOH$,	80° C.	. . .	Beeswax.
Melissic acid,	$C_{29}H_{59}COOH$,	90° C.	. . .	"

MONATOMIC ACIDS.

$$C_nH_{2n}O_2 = C_nH_{2n} + {}_1COOH.$$

Of the large number of acids in this group, we shall notice formic, acetic, butyric, valerianic, palmitic, oleic, and stearic.

Formic Acid, CHO—O—H, is a colorless liquid, of a very acid reaction and sharp, pungent odor. It boils at about 100° C. (212° F.) and solidifies at about 0° C. (32° F.). It exists ready formed in the red ant, stinging nettle, and pine needles. It acts as a reducing agent, reducing silver and mercury salts and depositing the metals. It is used in silvering glass, to reduce the silver which deposits upon the walls of the containing vessel. The best method of obtaining it is by heating to about 100° to 110° C. (212° to 230° F.) pure anhydrous glycerin and dry oxalic acid, adding more oxalic acid from time to time, and continuing the distillation. Carbon monoxide dissolved in potassium hydroxide, yields some potassium formate.

Acetic Acid, C_2H_3O—O—H, occurs in the form of acetates, in some vegetable and animal fluids. It is usually obtained by the fermentation of saccharine fluids, after they have undergone the alcoholic fermentation, or by the dry distillation of wood, starch, etc.

In distilling wood, gases, methyl alcohol (wood spirit), acetic acid, water, creasote, and tar are obtained. The liquid portion is distilled at a gentle heat, when the alcohol is separated. The remaining liquid, containing the acetic acid, is saturated with sodium carbonate, evaporated to dryness, and heated to 250° or 350° C. (482° to 662° F.) to char the tarry matters. The residue, containing sodium acetate, is dissolved in water, filtered, evaporated and allowed to crystallize out. If the free acid is desired, the residue, after carbonizing, is distilled with a slight excess of sulphuric acid. This gives a colorless, strongly acid, sour-smelling liquid, which crystallizes at about 17° C. (63° F.) and is known as glacial acetic acid.

Acetic acid, applied to the skin, blisters and causes considerable pain. When not too strong it acts as a styptic. It is soluble in water, alcohol and ether in all proportions. It dissolves resins, camphor, fibrin, and coagulated albumin. It precipitates mucin, and is used to separate this body from its solutions. It is also used, with the aid of heat, as a test for albumin; but care is taken not to add too much, as it dissolves the albumin. Under the action of chlorine, acetic acid furnishes a series of chlorine substitution compounds, in which the chlorine is substituted for the hydrogen of the radical; thus, we have monochlor-, dichlor-, and trichlor-acetic acids.

$$C_2H_2ClO_2H,\ C_2HCl_2O_2H, \text{ and } C_2Cl_3O_2H.$$

The last of these is mentioned elsewhere as a test for albumin in urine.

Vinegar.—This name is given to the mixture obtained by the fermentation of wine, cider, whiskey, molasses, infusion of malt, etc., under the influence of the growth of **mycoderma aceti**, and should contain at least four per cent. of acetic acid.

$$C_2H_5OH + O_2 = C_2H_3O{-}O{-}H + H_2O.$$

Alcoholic fermentation always precedes the acetous.

As vinegar always contains more or less of this ferment, called mother of vinegar, it is customary to add some of this fluid to start the process. The fermentation takes place slowly, in vats or casks, because of the small amount of surface presented to the air. The process is rendered very much more rapid by allowing the fluid to trickle over beech-wood shavings or chips, placed upon trays or in perforated barrels, so as to expose a large surface to the air. After having passed over the shavings four times, it will be found to be pretty thoroughly acetified. The temperature should be kept at about 25° C. (77°F.).

The vinegar of the market is frequently adulterated with—1, water; 2, mineral acids, especially sulphuric; 3, metallic impurities, as arsenic, lead, zinc, copper and tin; 4, wood vinegar; 5, organic substances, such as coloring matters, capsicum, etc. The addition of water can only be detected by the estimation of the per cent. of acetic acid.

The most objectionable adulterant is sulphuric acid. The simplest method of detecting free mineral acids is to evaporate a portion of the vinegar to dryness; heat the residue to dull redness for some time, to convert the acetates of the alkaline metals into carbonates, which salts can easily be detected by their effervescence with hydrochloric acid. If any free mineral acid existed in the vinegar, it would expel the acetic acid from the alkali metals, and convert them into inorganic salts, which remain unchanged on ignition.

Another test for mineral acids is methyl violet. Two or three drops of a solution of this compound (0.1 to 100) is added to 25 c.c. of vinegar. If .2 per cent. of any mineral acid be present, the color is blue; if .5 per cent., blue-green; if 1 per cent., green.

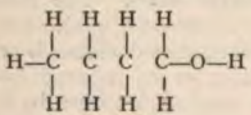
A simple test for sulphuric acid is to evaporate a portion to dryness in a white porcelain dish, with a little cane sugar. Near the end of the process, the residue becomes black by the charring of the sugar by the acid. A small quantity of sulphuric acid is sometimes added to make the vinegar keep. The poisonous metals likely to be found are mercury (corrosive sublimate), copper, arsenic, and lead. These metals may be detected by saturating the vinegar with hydric sulphide, or by separate tests for each. Burnt sugar, capsicum, etc., may be detected by taste or odor in the residue left on evaporation. The acetates are eliminated from the body as carbonates.

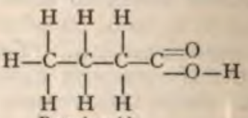
Propionic Acid, $C_2H_5\overline{C{=}O}OH$, is a colorless liquid, boiling at 140° C. (284° F.) It resembles acetic acid in odor and taste. Its salts are soluble and crystallizable. It is best prepared by heating ethyl cyanide—propio-nitril—with KOH until the odor of ether has disappeared, when the propionate of potassium is obtained. The acid may be obtained by decomposing this salt with H_2SO_4. The acid is produced during the putrefaction of various organic bodies, and in the destructive distillation of wood and of resin.

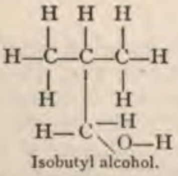
Butyric Acid ($C_4H_7O.O—H$).—This acid is found with other fatty acids, in butter, human perspiration, fæces, flesh juice, and in some beetles. It exists in butter as a glycerid or glyceric ether. Pathologically, it appears in a free state in urine, blood, and ovarian cysts, and in the sputa of gangrene of the lung and bronchiectasis. It also appears in the intestinal contents, as the result of a secondary fermentation of saccharine articles of food.

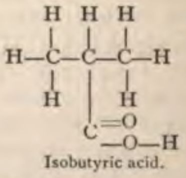
It is best prepared by maintaining at a temperature of 35° to 40° C. (95° to 104° F.) a solution of sugar containing lime or chalk, and sour milk or rotten cheese. A mixture of 10 parts of sugar, 1 part of cheese and 10 parts of chalk, answers very well. Lactate of calcium is first produced, which afterward changes, under the influence of the ferment of cheese, into butyrate of calcium. The solution should remain alkaline or neutral. Carbon dioxide and hydrogen are set free. When the fermentation is finished, 30 or 40 parts of crystallized sodium carbonate are added, and the mixture warmed and filtered. The filtrate is evaporated nearly to dryness, and hydrochloric or sulphuric acid added, which sets free the butyric acid as an oily layer, which may be purified by distillation. It boils at 162° C. (323° F.). It is a colorless liquid, with the characteristic penetrating odor of rancid butter. It is soluble in pure water, but separates if soluble salts are added to the solution. It is soluble in alcohol, oils, and ether. The butyrates are all soluble in water.

Isobutyric acid, an isomer of the foregoing, is obtained by the oxidation of secondary or isobutylic alcohol. The following graphic formulæ show the constitution of these bodies:—


Butylic alcohol.


Butyric acid.


Isobutyl alcohol.


Isobutyric acid.

Valeric or **Valerianic Acids,** C_5H_9COOH.—There are four possible isomeric valerianic acids, corresponding to the four amyl alcohols. Three are known.

Normal Valerianic Acid, $\overline{CH_3}\overline{CH_2}\overline{CH_2}\overline{CH_2}\overline{COOH}$, occurs in angelica and valerian roots, and its ammonium salt is formed by the putrid fermentation of albuminoid matters. It is sometimes found in the urine and fæces in smallpox, typhus fever, and yellow atrophy of the liver. It is obtained by distilling the powdered root with water. It is best prepared by the oxidation of amylic alcohol. A mixture of one part of amyl alcohol and four parts of concentrated sulphuric acid is run slowly into a retort containing four parts of water and five of potassium dichromate. The first product is valeraldehyde, which distils over. By elevating the beak of the retort so as to run the aldehyde back into the oxidizing mixture, it is changed into valerianic acid. The mixture is finally distilled, the distillate neutralized with sodium carbonate, evaporated and decomposed with sulphuric acid.

Valerianic acid is a thin, oily liquid boiling at 175° C. (347° F.), and possessing a sour, old cheese odor. The most of the valerianates are soluble in water, and, when moist, smell like the acid.

Valerianates of ammonium, bismuth, caffeine, quinine, iron, and zinc are used in medicine.

Palmitic Acid, $C_{15}H_{31}COOH$, is the first of the fatty acids, properly so called, which occurs in the animal fats and forms true soaps with the alkalies. On a large scale palmitic acid is made from palm oil. The oil is decomposed, in a still, by superheated steam at a temperature of about 315° C. (599° F.). When the condensed liquid is run out into receivers, it separates into two layers, the upper of which consists of the free fatty acids. On cooling, palmitic acid forms a white crystalline solid, and is used for making candles. It may also be prepared on a smaller scale by boiling palm oil with potassium carbonate, which converts it into potassium palmitate and oleate. On decomposing these salts with dilute H_2SO_4, the mixture of palmitic and oleic acids separates. This is washed, dried, and dissolved in hot alcohol, from which the palmitic acid crystallizes, leaving the oleic acid in solution. Palmitic acid crystallizes in needles which fuse at 62° C. (143.6° F.). It decomposes by distillation, except in the presence of water. **Adipocere,** a wax-like mass which is sometimes left when animal bodies decompose in the earth, is a mixture of the palmitates of calcium, potassium and occasionally ammonium. This substance is formed especially in bodies buried in damp soil, or in bodies which remain in the air some time after death. It is found to occur in muscles in a definite order. The amount of adipocere present is a good gauge of the time a body has been dead. Palmitic acid is insoluble in water, and is soluble in alcohol and ether.

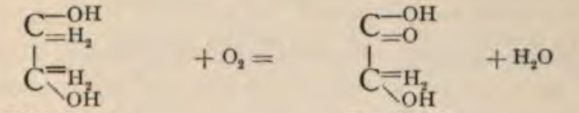
Stearic Acid, $C_{17}H_{35}COOH$, exists as a glycerid in all solid animal fats, and in many oils. It may be prepared from tallow by boiling it with potassium carbonate, decomposing the resulting soap with HCl, drying, separating the fatty acids and dissolving in a large quantity of hot alcohol. Afterward, the hot solution in alcohol is partly precipitated by a strong solution of barium acetate. The precipitate is decomposed with HCl, when stearic acid precipitates. This is collected, washed, dried, and recrystallized from alcohol. Stearic acid is a white, crystalline solid of the same sp. gr. as water, fusing at 69° C (156.2° F.). Stearic acid exists in fats as stearin, mixed with palmitin and olein. These glycerids may be saponified by superheated steam. Stearic acid is insoluble in water, but soluble in alcohol and ether. It burns with a luminous flame, and is much employed in the manufacture of candles and soaps. The so-called **stearine candles** are a mixture of palmitic and stearic acids. Both palmitic and stearic acids are found in the free state in the intestines during the digestion of fats, a portion of which are decomposed by the action of the pancreatic juice, and sometimes found as white masses in the stools.

Margaric Acid, $C_{16}H_{33}COOH$, is synthetically obtained. The substance formerly known by this name, and supposed to exist in natural fats under the name of margarin, is a mixture of palmitic and stearic acids.

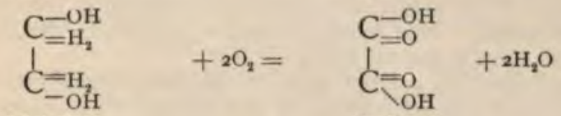
Oleic Acid—Acidum Oleicum (U. S. P.)—$C_{17}H_{33}COOH$, occurs as olein in most fats and oils. It is prepared by boiling olive oil with potassium carbonate, decomposing the solution with HCl, collecting the oily layer which separates, and heating it with litharge to 100° C. (212° F.) for some hours, when a mixture of oleate, palmitate, and stearate of lead is formed. The oleate is dissolved out of the mixture with ether, and the solution shaken with HCl to precipitate the lead. The ether is then distilled away and the impure oleic acid is dissolved in ammonia and precipitated by $BaCl_2$. The barium oleate is recrystallized from alcohol, and finally decomposed by tartaric acid. Oleic acid is a yellowish or brownish-yellow, oily liquid, having a peculiar lard-like odor and taste, and becomes darkened on exposure to the air. Sp. gr. is about .900. It is insoluble in water, soluble in alcohol, chloroform, benzene, oil of turpentine, and other fixed and volatile oils. At about 4° C. (39° F.) it becomes semi-solid, and at lower temperatures a whitish, solid mass. It cannot be distilled without decomposition, except in the presence of steam. When heated to about 95° C. (203° F.) it begins to decompose, giving off acrid vapors. Its alcoholic solution has a faintly acid reaction upon litmus paper. Equal volumes of oleic acid and alcohol should give a clear mixture at ordinary temperatures, but if any oil be present, it separates in drops. Oleic acid is a by-product in the manufacture of candles. The commercial acid absorbs oxygen readily when exposed to the air. By the action of nitrous acid, or nitrous fumes, oleic acid is converted into isomeric elaidic acid, a solid crystalline acid, fusing at 45° C. (113° F.). This acid is formed in the preparation of **unguentum hydrargyri nitratis** (U. S. P.). The nitrous fumes given off convert the oleic acid of the oil or lard into elaidic acid, which exists in the ointment in combination with mercury.

ACIDS DERIVED FROM GLYCOL.

The glycols, it will be remembered, are diatomic alcohols, and by oxidation may give rise to two series of acids, thus:


Ethyl glycol. Glycolic acid.

and

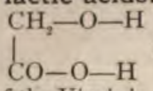

Ethyl glycol. Oxalic acid.

The other glycols can in the same manner furnish both series of acids, the one diatomic and monobasic, and known as the **lactic acid series,** and the other dibasic and known as the oxalic (or succinic) series. These glycols and acids are as follows:

Glycol Series.	Lactic Series.	Oxalic Series.
$C_2H_4(OH)_2$ Ethyl glycol.	$CH_2\begin{matrix}—COOH\\—OH\end{matrix}$ Glycolic acid.	$\begin{matrix}CO.OH\\ \vert \\CO.OH\end{matrix}$ Oxalic acid.
$C_3H_6(OH)_2$ Propyl glycol.	$C_2H_4\begin{matrix}—COOH\\—OH\end{matrix}$ Lactic acid.	$CH_2\begin{matrix}—COOH\\—COOH\end{matrix}$ Malonic acid.
$C_4H_8\begin{matrix}—OH\\—OH\end{matrix}$ Butyl glycol.	$C_3H_6\begin{matrix}—COOH\\—OH\end{matrix}$ Oxybutyric acid.	$C_2H_4\begin{matrix}—COOH\\—COOH\end{matrix}$ Succinic acid.

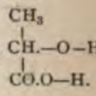
DIATOMIC AND MONOBASIC ACIDS.

But two acids of this group are worthy of special mention; viz.: **glycolic** and **lactic acids.**

Glycolic Acid,  $\begin{matrix}CH_2—O—H\\ \vert \\CO—O—H\end{matrix}$ is found in unripe grapes, and in the green leaves of the Virginia creeper. When pure, it forms large, regular crystals, which deliquesce in moist air, and melt at 79° C. (174° F.).

Lactic Acid—Hydroxy-propionic Acid—Acidum Lacticum (U. S. P.).—There are at least three isomeric lactic acids known, and a fourth has been described. Their graphic formulæ are:

$CH_3.CHOH.COOH.$	$CH_2OH.CH_2.COOH.$
Ethylidene-lactic acid.	Hydracrylic or Ethylene-lactic acid.

In addition to these, sarcolactic acid is well-known,  $\begin{matrix}CH_3\\ \vert \\CH.—O—H.\\ \vert \\CO.O—H.\end{matrix}$

Lactic acid is the acid of sour milk and sour cabbage, and is produced by a special ferment, the **bacterium lactis,** or **lactic ferment,** It is found in small quantities in the gastric juice, urine, and intestinal juices.

It is produced on a large scale by the lactic fermentation of cane sugar and glucose. Flour is first treated with dilute sulphuric acid, to convert the starch into glucose; the free acid is then neutralized with milk of lime. To this is then added sour milk, and it is allowed to ferment; care being taken to stop the process before butyric acid fermentation sets in, by heating the mixture to boiling. The hot solution of calcium lactate is separated by filtration, evaporated down, and allowed to crystallize. From this salt, the acid may be obtained by saturation with sulphuric acid. It has been prepared synthetically by the oxidation of propyl glycol. A solution containing 75 per cent. of the acid is official in the U. S. P. It is a colorless, syrupy, odorless, very acid liquid, freely miscible with water, alcohol, and ether. It has been used to check lactic and butyric fermentation in the intestinal tract, as an excess of this acid prevents the further growth of the ferment. It has been prepared synthetically by heating aldehyde with hydrocyanic acid. It is used in the preparation of syrup of the lactophosphates (U. S. P.).

Ferrous Lactate, Ferri Lactas, U. S. P., $Fe(C_3H_5O_3)_2.3H_2O$.—It occurs in pale, greenish-white, odorless, crystalline crusts or grains, permanent in the air, and soluble in water.

Strontium Lactate, Strontii Lactas, U. S. P., $Sr(C_3H_5O_3)_2.3H_2O$, also used in medicine, occurs as a white, granular powder, soluble in water.

Sarcolactic Acid, or **Paralactic Acid,** is isomeric with the above. It has not been prepared synthetically, but is characteristic of muscle juice, and gives to muscular tissue its acid reaction. It occurs in the blood, especially after active muscular exercise. It is found in the urine, and in increased amount after violent muscular exertion, and very strikingly after extirpation of the liver in birds and frogs. It has been found in the fluid of ovarian cysts, and other pathological fluids. It is found in extracts of beef, and may be prepared from Liebig's extract after precipitating with alcohol, acidifying with H_2SO_4, and shaking the filtrate with excess of ether, which dissolves it. On evaporating the ether, dissolving the residue in water and precipitating with zinc acetate, the zinc salt is obtained. By recrystallizing this salt, suspending it in water, and decomposing with hydrosulphuric acid gas, the acid is obtained in solution. It may be separated by dissolving it out with ether. The acid thus obtained is similar in most of its physical and chemical properties to ordinary lactic acid. It is dextro-rotary, however, while ordinary lactic acid is optically inactive.

Sarcolactic acid obtained from muscular tissue is said to contain another acid, known as ethylene-lactic acid, in small quantities.

Dead muscle has an acid reaction, which is greater as rigor mortis appears. During life, the acidity increases with active contraction, and diminishes with rest. The acid is probably produced by the decomposition of the muscular tissue during contraction, although some have claimed that the acidity is due to acid phosphates produced from the phosphates of the tissue during contraction, while others have thought that the lactic acid is due to the transformation of the glycogen usually found in muscle.

Lymphatic, thymus, and thyroid tissues are alkaline during life, but become rapidly acid after death, from the presence of sarcolactic acid.

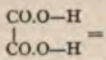
Tests for Lactic Acids.—Both of these acids give an intense yellow color with a very dilute solution of ferric chloride.

If to about 10 c. c. of water two drops of carbolic acid and a drop of ferric chloride solution be added, and to this violet solution a mere trace of lactic acid be added, it instantly changes to yellow (Uffelmann).

This test will show one part of the acid in 10,000 parts of water.

Oxybutyric Acid is found in the urine of diabetics, and is mentioned in the chapter on the urine.

DIBASIC ACIDS.

Oxalic Acid,  $\begin{array}{l}CO.O{-}H\\|\\CO.O{-}H\end{array} = H_2C_2O_4$.—This important acid occurs in many plants (Oxalis, Rumex, Rheum) as acid calcium or potassium oxalates. Calcium oxalate is also found in the urine.

Oxalic acid is easily obtained by acting upon many organic substances with oxidizing agents. Glycol, glycolic, or acetic acids may be made to yield it. It is best prepared from the carbohydrates (sugar, starch, etc.), by treating them with strong nitric acid, or by fusing with caustic potash. Commercial oxalic acid is prepared by fusing sawdust with a mixture of caustic soda and potash, and treating the oxalates thus formed with hydrochloric acid. The acid crystallizes in colorless prisms with two molecules of water which they lose at 100° C. (212° F.). It is soluble in eight parts of cold water, and in alcohol. On heating the acid, it is resolved into carbon monoxide, dioxide, water and formic acid. Strong oxidizing agents convert it into carbon dioxide and water. It is a strong dibasic acid, and forms both acid and neutral salts with most of the metals.

Oxalic acid easily oxidizes into CO_2 and H_2O. This may be effected by chromic acid, potassium permanganate in presence of dilute H_2SO_4, and even on exposure of its watery solution to air and sunlight. Dehydrating agents, H_2SO_4, and H_3PO_4, decompose it into CO, CO_2 and H_2O. Oxalic acid resembles magnesium sulphate, and has been taken by mistake for this salt.

Oxalic acid is both a corrosive and systemic poison. Death has followed the use of ʒj (4 grms.), but persons have recovered after taking much larger doses. Much will depend upon the concentration of the poison. When the solid or a strong solution is taken, its local effect is most marked, and death may come within half an hour. If recovery takes place, owing to prompt treatment, the after effects will be those of any of the corrosive poisons. If the acid is taken in dilute solution, the local effect is much less, or almost wanting. In such cases the poison is absorbed, and acts as a systemic poison. Vomiting and cramps are usually, though not always, present. The soluble salts of oxalic acid are almost as poisonous as the acid, but do not have the same local corrosive effect.

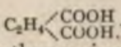
The treatment should be prompt and judicious. It is important to learn, if possible, the condition in which the acid was swallowed. If in concentrated solution or as the solid, the stomach pump, or even the stomach tube, should not be used. If taken diluted, and the burning epigastric pain is not too severe, the soft stomach tube may be used with care, washing the stomach out thoroughly with lime water, followed with pure water. If lime water is not procurable, milk of magnesia or a solution of magnesium sulphate (epsom salts) may be used, If it is deemed unsafe to use the tube, vomiting may be induced, and the stomach washed out by giving a lukewarm mixture of equal quantities of lime water and sink or well water.

Tests for Oxalic Acid.—Calcium chloride gives, even in very dilute, neutral or alkaline solutions, a fine, white, heavy precipitate. The precipitate is soluble in HCl, but not in acetic acid.

Silver nitrate gives a white precipitate, soluble in HNO_3 and in NH_4OH.

Lead acetate gives, in not too dilute solutions, a white precipitate, soluble in HNO_3, but not in acetic.

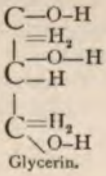
It discharges the color of $K_2Mn_2O_8$ in presence of dilute H_2SO_4.

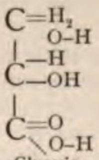
Succinic Acid,  $C_2H_4\begin{matrix}\diagup COOH\\ \diagdown COOH\end{matrix}$.—This acid is found ready formed in amber and some other resins, in several plants, in the spleen, in thymus and thyroid glands, in hydrocephalic and hydrocele fluids. It is obtained in small quantities in alcoholic fermentation and in the putrefaction of proteids.

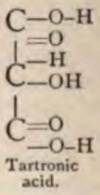
It may be prepared by the spontaneous fermentation of tartaric or malic acids. It is one of the products of alcoholic fermentation of sugar, and may be prepared by the action of reducing agents on malic and tartaric acids. It may be obtained in quantity by the dry distillation of amber; the aqueous portion of the distillate is heated to boiling, and filtered; on cooling, crude succinic acid crystallizes out. Succinic acid crystallizes in monoclinic prisms, melting at 180° C. (356° F.), and decomposing into water and succinic anhydride at 235° C. (455° F.). It is soluble in 23 parts of cold water, and very freely soluble in hot water. By adding neutral solution of ferric chloride to a soluble succinate, a brown, gelatinous, ferric succinate is produced; this reaction is used as a qualitative test for the acid. The succinates of the alkaline metals are soluble; those of the other metals are either slightly soluble or insoluble.

There are two isomeric succinic acids, but iso-succinic acid is unimportant.

Dibasic Acids Containing Alcoholic Hydroxyl.—The simplest acid of this class must contain three carbon atoms, and in that case may be regarded as being derived from the triatomic alcohol, glycerin. By the oxidation of glycerin we may form two acids, thus:—


Glycerin.


Glyceric acid.

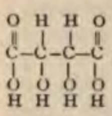

Tartronic acid.

Malic Acid – Oxy-succinic Acid—$C_2H_3\begin{cases}\text{CO O–H}\\ \text{O–H}\\ \text{CO O–H,}\end{cases}$ may be viewed as a homologue of tartronic acid, or as derived from succinic acid. It occurs in many acid fruits, as cherries, apples, raspberries, gooseberries, rhubarb (stalks and leaves), unripe mountain ash berries, unripe grapes and quinces. It is best prepared by nearly saturating the boiled and filtered juice of the berries of the mountain ash with milk of lime. On continued boiling, calcium malate, $CaC_4H_3(HO)O_4.H_2O$, separates as a crystalline powder, from which the acid may be obtained by treatment with dilute nitric acid. Malic acid crystallizes in groups of small, colorless, deliquescent crystals. It melts at 100° C. (212° F.), and decomposes at 150° C. (302° F.). Putrefactive ferments convert malic into acetic, succinic, butyric and carbonic acids.

There are three isomeric malic acids possible, of which two are known. The alkaline malates are soluble; other malates are slightly soluble or insoluble; all are crystalline.

The malates are easily oxidized, and are converted into carbonates in the animal body.

Tartaric Acid — Acidum Tartaricum (U. S. P.) —



$$\begin{array}{cccc} O & H & H & O \\ \| & | & | & \| \\ C- & C- & C- & C \\ | & | & | & | \\ O & O & O & O \\ H & H & H & H \end{array}$$

is a diabasic, tetratomic acid. (Compare the formulæ of succinic, malic, and tartaric acids.) Four isomeric tartaric acids are known; two of which—dextro and lævo-tartaric acids—are optically active, and two—racemic and mesotartaric acids—are optically inactive. Ordinary, or **dextro-tartaric acid** is found in many fruits, particularly in ripe grapes, as acid potassium tartrate (**cream of tartar**), which, during the fermentation of the must, is deposited, mixed with yeast, coloring matter, calcium tartrate, etc., as a brown crust, or deposit, known as crude **argol.** Tartaric acid is prepared from argol by first treating with hot water, filtering, decolorizing with animal charcoal, converting the acid potassium tartrate into calcium tartrate by the addition of milk of lime, then decomposing this with sulphuric acid. Tartaric acid is thus obtained in solution, and may easily be separated by crystallization. Tartaric acid is usually made in the same factories where **cream of tartar** is prepared in large quantities. It usually occurs in beautiful, oblique prisms, permanent in the air, soluble in one-half their weight of water, or in 2.5 parts of alcohol, and insoluble in ether. When heated, it melts at 135° C. (275° F.), and forms metatartaric and pyrotartaric acids, and tartaric anhydride ($C_4H_4O_5$). At a higher temperature it decomposes, with a burnt-sugar odor.

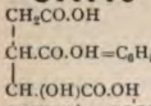
Tartaric acid has a strong, acid taste. It precipitates calcium in neutral or alkaline solutions, but not in strong acid solutions. Ammonium salts prevent this precipitation. Heated with hydriodic acid and phosphorus, tartaric is first changed into malic, and then into succinic acid.

The principal tartrates are the neutral and acid potassium tartrates, sodio-potassium tartrate (**Rochelle Salt**) and **tartar emetic,** or antimonyl potassium tartrate, all of which are mentioned in another place. Ferro-potassium tartrate and ferro-ammonium tartrate are also used in medicine. They both belong to the class of substances known as **scale compounds**; *i. e.*, compounds which do not crystallize readily, and are prepared by spreading the material, evaported to a syrup, upon plates of glass to dry, and then scraping off the thin scales. The above-mentioned compounds occur in the form of garnet-red scales, slightly deliquescent, very soluble in water, but insoluble in alcohol. Tartaric acid is used in making effervescing drinks, in calico printing, and by confectioners, to prevent the crystallization of the sugar. When taken in too large quantities, it acts as an irritant poison. One ounce has caused death.

When taken in not too great quantity, its salts are oxidized to carbonic acid, but if taken in very large quantity it may escape complete destruction, and may appear in the urine and perspiration. It is, therefore, not so easily oxidized as malic, succinic, and some other organic acids.

TRIBASIC ACIDS.

Citric Acid — Acidum Citricum (U. S. P.) —



$$\begin{array}{l} CH_2CO.OH \\ | \\ CH.CO.OH \\ | \\ CH.(OH)CO.OH \end{array} = C_6H_5O_4(OH)_3.$$

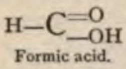
—This acid occurs in the juice of lemons, currants, gooseberries, beet roots and other plants. It is manufactured on a large scale from lemon juice, which is clarified by boiling it with albumin, and then saturated, while hot, with powdered chalk or milk of lime. The precipitated calcium citrate is decomposed by an equivalent quantity of sulphuric acid, and filtered from the resulting gypsum. On evaporating the filtrate, the acid crystallizes out in large, transparent, rhombic prisms, having an agreeable, sour taste, and containing one molecule of water of crystallization. The acid melts between 135° and 152° C. (275° and 305 6° F.), and is readily soluble in water and alcohol. At 175° C. (347° F.), the acid loses water, and is converted into **aconitic acid**, $C_6H_3O_3(OH)_3$.

Solutions of citric acid soon develop mould, and are thereby decomposed. Citric acid forms three classes of well-defined salts with the metals. Citrates of the alkaline metals are soluble in water. The citrates are decomposed into carbonates in the body, and, in case of the citrates of the alkalies, are eliminated by the kidneys as carbonates; hence, these citrates are frequently prescribed in acid conditions of the urine. Citric acid is not known to exert any injurious action upon the economy, even in considerable quantities.

Citrates of bismuth, iron, iron and ammonium, iron and quinine, iron and strychnine, lithium, potassium, bismuth and ammonium, solution of magnesium citrate, and syrup of citric acid are official. When boiled with excess of lime water, citric acid precipitates basic calcium citrate. This distinguishes it from oxalic and tartaric acids.

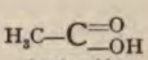
Meconic Acid, $C_4OH(CO.OH)_3$, is found in opium, in combination with the alkaloids. It may be prepared by dissolving in hot water, neutralizing with $CaCO_3$ and then precipitating with $CaCl_2$. The precipitate may be dissolved in hot dilute HCl and the acid crystallized out. The acid occurs in crystalline plates, dissolving rather sparingly in cold, but easily in hot water and alcohol. Ether dissolves it but sparingly. It has an astringent taste. Solutions of meconic acid give a blood-red color with ferric chloride, which is not discharged by $HgCl_2$, or dilute acids, but is discharged by stannous chloride and sodium hypochlorite.

The relation of the foregoing acids will be seen by the following graphic formulæ :



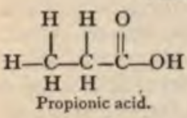
$H-C\genfrac{}{}{0pt}{}{=O}{-OH}$

Formic acid.



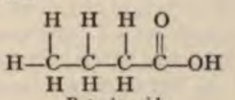
$H_3C-C\genfrac{}{}{0pt}{}{=O}{-OH}$

Acetic acid.



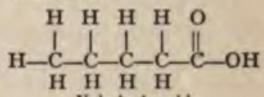
$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Propionic acid.



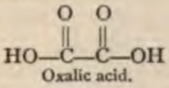
$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Butyric acid.



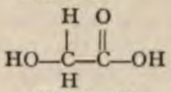
$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Valerianic acid.



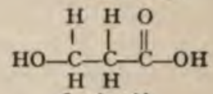
$HO-\overset{O}{\overset{\|}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Oxalic acid.



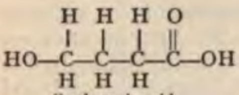
$HO-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Glycolic acid.



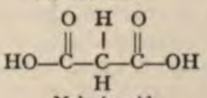
$HO-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Lactic acid.



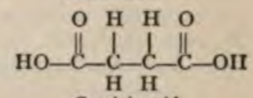
$HO-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Oxybutyric acid.



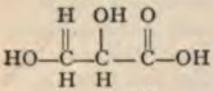
$HO-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Malonic acid.



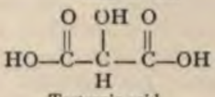
$HO-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Succinic acid.



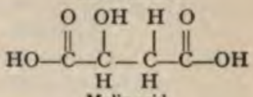
$HO-\underset{H}{\overset{H}{\overset{\|}{C}}}-\underset{H}{\overset{OH}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Glyceric acid.



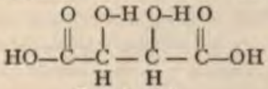
$HO-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{OH}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Tartronic acid.



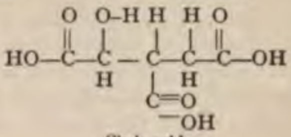
$HO-\overset{O}{\overset{\|}{C}}-\overset{OH}{C}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Malic acid.



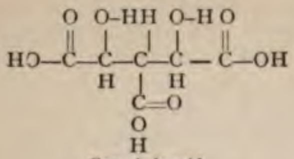
$HO-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{O-H}{C}}-\underset{H}{\overset{O-H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Tartaric acid.

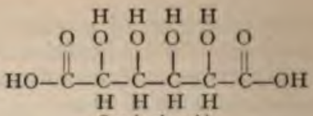


$HO-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{O-H}{C}}-\underset{\underset{C\genfrac{}{}{0pt}{}{=O}{-OH}}{|}}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

Citric acid.



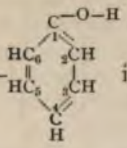
Oxy-citric acid.



Saccharic acid
and
Mucic acid.

THE PHENOLS.

Compounds derived from the Aromatic or Benzene Hydrocarbons.—It has been thought best to study the derivatives of the benzene hydrocarbons by themselves, because of certain peculiarities of these compounds, and to avoid making the study of the others too complicated. We have already studied the principal hydrocarbons of this series which interest the physician and pharmacist. The H atoms in benzene may be replaced by halogens, hydroxyl, sulphur or other hydrocarbon radicals. In fact the higher members of the series are all produced by substitutions for H in the original benzene nucleus. By the substitution of Cl, Br or I for H in the principal chain, or in the lateral chain. we may form a very great number of compounds, few of which are of sufficient interest to claim special study. By the substitution of hydroxyl for H in benzene, we have what is termed a phenol. By the substitution of two hydroxyls for two atoms of H in benzene we have the di-atomic phenols. By the substitution of three hydroxyls we have the tri-atomic phenols. It will be seen that in the higher homologues of benzene, in toluene for example, $C_6H_5CH_3$, where there is a side chain, it is possible to substitute the hydroxyl for one of the H atoms of the benzene nucleus, or for one on the side chain. In the first instance we have a phenol, in the second we have an alcohol. That is, the first cannot be oxidized to produce an acid, because the carboxyl group COOH cannot be produced. In the second we can form COOH by oxidation, and it is therefore a true alcohol. The phenols, therefore, are isomeric with, but have different properties from the alcohols. The phenols differ from the alcohols, in not furnishing corresponding aldehydes and acids on oxidation; in not dividing into water and hydrocarbons under the influence of dehydrating agents, as all alcohols should; and in not reacting with acids to form ethers. The phenols form with metallic elements, more stable compounds than the true alcohols. These compounds resemble the salts rather than the alcoholates; *i. e.*, the phenols exhibit acid properties, while in structure they are allied to the alcohols.

Phenol — Phenic Acid — Calbolic Acid — Acidum Carbolicum (U. S. P.)— 

is met with in the products of the destructive distillation of coal and wood, and is found in small quantities in human urine, and in castoreum. In the arts, it is prepared from that portion of the coal tar oil distilling between 150° C. (302° F.) and 190° C. (374° F.). This is agitated with a concentrated solution of caustic soda, when a crystalline carbolate of sodium is formed, while the neutral oils are left unacted upon. After the latter have been separated, the carbolate is decomposed by hydrochloric acid, and the impure carbolic acid thus obtained, again treated with sodium hydroxide. On exposing this solution to the air, the greater portion of the impurities becomes oxidized, and separates as a tarry mass. The clear solution of sodium phenate (or carbolate) is again decomposed by hydrochloric acid, and the resulting carbolic acid separated and submitted to distillation. From the portion passing over below 190° C. (374° F.) phenol separates out as colorless needles on cooling, which melt at 42° C. (108° F.), and boil at 184° C. (364° F.).

Pure phenol is a crystalline solid, having a characteristic odor and pungent, caustic taste, producing a white eschar with animal tissues. The crystals are liquefied by the addition of about 5 per cent. of water. This liquid is made turbid by the addition of more water, until 2000 parts are added, when the acid dissolves to a clear solution. It is soluble in twenty parts of water at the ordinary temperature. The addition of glycerin increases its solubility. It is readily soluble in alcohol, ether, benzene, carbon disulphide, glycerin, and fixed and volatile oils. Carbolic acid coagulates albumin, and its aqueous solution gives a permanent violet-blue color with ferric chloride, while that produced by creasote is first green and then brown. It forms with bromine water, a white precipitate of tribromphenol. When quite pure, carbolic acid is permanent in the air; but the commercial acid frequently changes to a pink or red color. Ammonia and chlorinated soda solution produce a blue color with carbolic acid. Carbolic acid is very much used as an antiseptic, in medicine and in the arts. Some of the carbolates have also been used for the same purpose. Carbolic acid is very poisonous when taken into the body, and cases of fatal poisoning by it are not uncommon. Dangerous symptoms have been produced by six or seven drops, and fatal poisoning has occurred from its use as a surgical dressing. The urine is dark colored and smoky in such cases, and its appearance should be watched while using the acid, either internally or locally.

Phenates.—When phenol is heated with KOH or NaOH the following reaction takes place:—

$$\underset{\text{Phenol.}}{C_6H_5OH} + KOH = \underset{\substack{\text{Potassium}\\\text{phenate.}}}{C_6H_5OK} + H_2O.$$

The phenol here acts as an acid, and gives rise to the name phenic acid or carbolic acid. Certain other metals and the alkaloids may be employed to replace the alcoholic H of phenol, to give phenates. Mercuric phenate, quinine phenate, and even other salts of this class have been employed in medicine.

Cresylic Acid, or **Cresol,** $C_6H_4\left\{\begin{matrix}CH_3\\OH\end{matrix}\right.$.—There are three possible compounds having this formula, the ortho, meta, and para cresol. Two of these, at least, are found in coal tar together with phenol, and obtained from it by fractional distillation. The impure varieties of commercial coal tar creasote, or carbolic acid, contain in addition cresylic acid or cresol. Cresol may be prepared by dissolving toluidin in sulphuric acid, adding potassium nitrite, and distilling with steam.

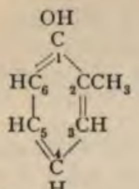
$$C_6H_4CH_3NH_2 + HNO_2 = C_6H_4CH_3OH + H_2O + N_2.$$

By the same method of preparation the three isomeric cresols are prepared from the three corresponding isomeric toluidins.

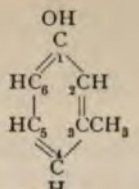
Ortho Cresol is a crystalline solid, fusing at 31° C. (88° F.), and boiling at 185° C. (365° F.).

Meta Cresol is a liquid boiling at 195° C. (383° F.).

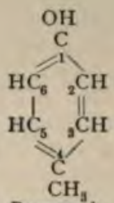
Para Cresol [illegible] F.) [illegible] the [illegible] The [illegible] —



Ortho-cresol.



Meta-cresol.



Para-cresol.

Tri-Cresol is a mixture of the three cresols in their natural proportions, carefully freed from all impurities. It is a colorless, oily liquid of sp. gr. of 1.045, and soluble in 40 parts of water, giving a clear neutral solution. Its disinfectant power is three times that of carbolic acid.

Para Cresol Benzoat, $C_6H_5COO.C_6H_4.CH_3$, is a crystalline compound, said to be a powerful disinfectant.

Beech-wood Creasote — Creosotum (U. S. P.) — is a mixture of phenols consisting chiefly of guaiacol and cresols obtained during the distillation of wood tar, preferably that of the beech. It contains, in addition to the above, a small quantity of phlorol. It is an almost colorless, yellowish or pinkish, highly refractive, oily liquid, having a penetrating, smoky odor and a burning, caustic taste. Its sp. gr. is 1.070 or higher. It is soluble in about 150 parts of water, but it does not form a perfectly clear solution. It is soluble in all proportions in alcohol, ether, chloroform, benzene, carbon disulphide, acetic acid, fixed and volatile oils. It begins to boil at about 205° C. (401° F.), and most of it distils between 205° and 215° C. (401° and 419° F.). When cooled to −20° C. (−4° F.) it does not solidify like carbolic acid, but becomes gelatinous. It is inflammable. Its solution gives a reddish-brown precipitate with bromine water, which distinguishes it from phenol.

Creasote is employed in medicine, both internally and externally and by inhalations. It is also employed as an antiseptic.

To distinguish creasote from phenol, which is often substituted for creasote, the following tests may be applied. Phenol gives with Fe_2Cl_6 a purple colored solution, while creasote gives a violet which rapidly changes to green and finally to brown, with the formation of a brown precipitate. Phenol is soluble in glycerin, while creasote is not. Phenol precipitates collodion from its solution, while creasote does not.

Creasote Carbonate is a mixture of guaiacol carbonate with some cresol. It is prepared by saturating partially purified guaiacol with sodium hydroxide, and treating this compound with carbonyl chloride ($COCl_2$). It is an amber-colored oil, honey-like in consistency, with a faint odor and taste of creosote. It is used as a substitute for creasote, it being free from its disagreeable taste.

The cresols possess wonderful antiseptic properties, and are less poisonous to the animal organism than phenol. A serious hindrance to their employment as germicides is their insolubility. Cresols have recently been introduced as disinfectants under special names, as creolin, lysol, solveol, and solutol. These substances seem to be derivatives from cresols. Creolin is a dark brown alkaline liquid. It is free from caustic or irritating properties, and may be administered internally. It forms with water a more or less turbid, or milky mixture or emulsion. It mixes with chloroform, ether, and dilute alcohol in all proportions. For external application, it is used in the form of an ointment, or as a 1 to 2 per cent. aqueous solution.

Lysol is a preparation resembling creolin in its properties, and is made by dissolving the fraction of tar oil, which boils between 190° and 200° C. in fat, and afterwards saponifying with alkalies, with the addition of alcohol. It is a brown, oily-looking, clear liquid, with an aromatic, creasote-like odor. It is said to contain 50 per cent. of cresols. It is miscible with water, forming a clear, saponaceous, frothing liquid; also with alcohol, benzene, chloroform, and glycerin. It is a good disinfectant, five times more active than phenol, and much less poisonous. It is non-caustic.

Solveol is a solution of sodium cresol in excess of cresol, and **solutol** a solution of cresol in cresylate of sodium. It is said to contain 60 per cent. of cresylic acid—one-fourth in the free state, and three-fourths combined with sodium **Cresol iodide** has also been introduced into medicine in the form of a light-yellow powder of not very pleasant odor. It is insoluble in water, but soluble in the oils, alcohol, ether, and chloroform.

Cresotic Acids—Oxytoluic Acids—$C_6H_4CH_3OHCOOH$.—There are three of these corresponding to the ortho-, meta-, and para-cresols. They are prepared by the action of sodium hydroxide and carbon dioxide upon the cresols, according to Kolbe's method of preparing salycilic acid from phenol. They may also be prepared by melting the homologues of phenol with excess of potassium hydroxide. The cresotic acids all crystallize in long white prismatic needles, which can be volatilized in a current of steam. They are soluble with difficulty in cold, but more so in hot water; readily soluble in alcohol, ether, and chloroform. In solution their reactions are similar to salicylic acid. Several salts of cresotic acid have been suggested as medicinal remedies. **Sodium cresotate,** and **sodium para-cresotate,** $C_6H_3\left\{\begin{matrix}CH_3\\OH\\COONa,\end{matrix}\right.$ have been used. The latter salt is a fine crystalline powder, with a bitter taste, soluble in 25 parts of water. It has been used in rheumatism, in doses of from 8 to 45 grains.

Dimethyl Phenols — Xenols — Xylenols, $C_6H_3,\left\{\begin{matrix}CH_3\\CH_3\\OH\end{matrix}\right.$ There are six possible dimethyl phenols, four of which have been obtained. We may also have three possible ethyl phenols, $C_6H_4\left\{\begin{matrix}C_2H_5\\OH.\end{matrix}\right.$

Thymol—Propyl-meta-cresol, $C_6H_3\left\{\begin{matrix}CH_3\\C_3H_7,\\OH\end{matrix}\right.$ has already been described among the Camphors. (See page 326.)

Carvacrol, or **Propyl-ortho-cresol,** $C_6H_3\left\{\begin{matrix}CH_3\\C_3H_7,\\OH\end{matrix}\right.$ exists in the essential oil of origanum. It is an isomer of thymol. It is a thick, oily liquid, which does not solidify even at — 25° C. (— 13° F.). It boils at 233° C. (451.4° F.). It is very soluble in chloroform, ether, and olive oil, but insoluble in water. Its iodide is a yellow-brown powder, sometimes employed in medicine. It is obtained by the action of iodine upon camphor. It is employed externally as a substitute for iodoform.

Carvacrol Iodide, $C_6H_3\left\{\begin{matrix}CH_3\\C_3H_7\\OI\end{matrix}\right.$ is prepared by the action of iodine upon an alkaline solution of carvacrol. It is a yellowish-brown powder, almost odorless, insoluble in water, slightly soluble in alcohol, but easily soluble in ether, chloroform, and olive oil. It has been proposed as a substitute for iodoform.

Eugenol, or **Eugenic Acid,** $C_6H_3\left\{\begin{matrix}OCH_3\\C_3H_5,\\OH\end{matrix}\right.$ is a body closely resembling carvacrol, obtained from the oil of cloves, cinnamon, bay, pimento or sassafras, by oxidation. Eugenol occurs as an aromatic liquid, boiling at 235° C. (455° F.), slightly soluble in water, freely so in alcohol. It is employed as an antiseptic, and is considered superior to phenol. It has also been used internally as a febrifuge. Several compounds of eugenol have also been employed, **benzoyl-eugenol**, cinnamyl-eugenol, iodo-eugenol, and eugenol-acetamid, being the principal ones.

Chlor-phenols and **Brom-phenols.**—When chlorine is passed into phenol, ortho- and para-chlor-phenols are formed. The corresponding Br and I substitution products are obtained by the action of these elements on phenol.

Mono-chlor-phenol, C_6H_4ClOH, has been employed as a remedy for inhalations in phthisis and other lung troubles. It is a volatile liquid having an odor somewhat resembling phenol.

Bromol, or **Tri-brom-phenol,** $C_6H_2Br_3OH$, also called tribromophenol, is prepared by the action of Br upon an aqueous solution of phenol. It occurs as a white, crystalline powder of an astringent sweetish taste, and an odor resembling that of Br. It melts at 95° C. (203° F.). It is insoluble in water, but soluble in alcohol, ether, chloroform, glycerin and the fatty and ethereal oils. It has been recommended as a local remedy in diphtheria and as an intestinal antiseptic.

A Di-iodo Thymol, $\left.\begin{matrix}C_3H_7\\CH_3\end{matrix}\right\} C_6H_2(IO)—(IO)C_6H_2 \left\{\begin{matrix}C_3H_7\\CH_3\end{matrix}\right.$, formed by the action of a solution of I in KI upon an alkaline solution of thymol, has been proposed as a substitute for iodoform, under the name of **annidalin.** It occurs as a reddish-brown, odorless powder, which is decomposed under the action of heat and light, with evolution of iodine. This substance is now more generally known as **aristol,** or **di-thymol di-iodide.** It is insoluble in water and glycerin, slightly soluble in alcohol and readily so in ether and collodion. It is taken up by fatty oils or vaseline when rubbed with them. When heated in a glass tube, iodine vapors are given off.

Tri-nitro-phenol — Picric Acid — Carbazotic Acid, $C_6H_2(NO_2)_3OH$.—The phenols are acted upon by strong nitric acid, forming mono-nitro, di-nitro and tri-nitro phenols. The first two of these are of little importance to the physician, but the third is employed in the arts as a yellow dye for silk and wool, and is frequently employed as a test for albumin in urine, and as a precipitant of the alkaloids. Two tri-nitro phenols are known, one in which the NO_2 group is attached to carbon atoms 1, 2 and 4, and in the other attached to 2, 4 and 6. The latter compound is ordinary picric acid. It is prepared by the action of strong nitric acid upon phenol, salicin, indigo, silk, wool and many other organic substances containing the benzene nucleus. It occurs in yellow crystalline plates. It is nearly odorless, and has an intensely bitter taste and an acid reaction. It is sparingly soluble in water, very soluble in alcohol, ether and benzene. When quickly heated it detonates. It forms salts with the metals which are explosives. When taken internally in considerable doses it acts as a poison.

Tests.—(1) Its taste is so bitter that this together with its bright lemon-yellow color serves as a delicate test.

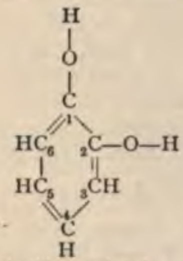
(2) Its solutions give a green crystalline precipitate with an ammoniacal solution of $CuSO_4$.

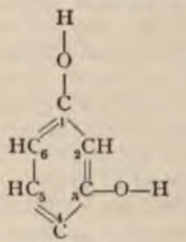
(3) Glucose heated with an alkaline solution of the acid gives a reddish-brown colored solution.

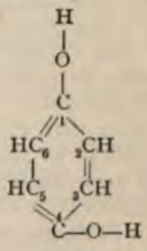
(4) It gives an intense red color when warmed with an alkaline solution of KCN.

DIATOMIC PHENOLS.

These compounds are derived from benzene and its homologues by replacing two atoms of hydrogen by hydroxyl. They may be prepared by fusing phenol-sulphonic acids with KOH. There are three such compounds possible, all of which, in the case of benzene, are well known. Their graphic formulæ and the cause of the isomerism is shown by the following :—


Ortho-dihydro-phenol.


Meta-dihydro-phenol.


Para-dihydro-phenol.

Ortho-dihydro-phenol, or **Pyrocatechin,** $C_6H_4\begin{cases}OH\ (1)\\OH\ (2)\end{cases}$ is another isomeride of hydroquinone that has found use as a remedial agent. It forms flat crystals or plates, readily soluble in water, alcohol and ether. It is prepared by distilling extract of catechu, kino and other extracts containing tannin. It is found in crude pyroligneous acid distilled from wood. It has weak acid properties.

Solutions of pyrocatechin reduce silver salts in the cold, and

Fehling's solutions on warming. If made alkaline they absorb oxygen from the air and turn green.

Pyrocatechin.	Resorcin.	Hydroquinone.
$C_6H_4(OH)_2(1:2)$	$C_6H_4(OH)_2(1:3)$	$C_6H_4(OH)_2(1:4)$

It will be observed that in the first formula the hydroxyls occupy positions on two adjoining carbon atoms, or 1 and 2. In the second the positions are 1 and 3, and in the third they are 1 and 4. These three include all the possible relative positions of two hydroxyl groups in this molecule. The properties change with the changed position of the second hydroxyl group.

Meta-dihydro-phenol Resorcin — Resorcinol, $C_6H_4\text{-}\left\{\begin{matrix}OH(1)\\OH(3)\end{matrix}\right.$, an isomeride of hydroquinone, has come into prominence recently in the treatment of certain maladies. It forms colorless crystals, melting at about 100° C. (212° F.), and boiling at 276° C. (528.8° F.). It is very soluble in water, alcohol, and ether, and possesses a sweetish, harsh taste. It is prepared by fusing certain gum resins (galbanum), extract of sapin-wood; or, by distilling Brazil-wood, with caustic potash. It is a strong antifermentative. It is now prepared synthetically from benzene, but the process is complicated.

When a small quantity is warmed with twice its weight of tartaric acid, and 10 drops of H_2SO_4, it gives dark carmine red liquid. A solution of 5 parts of resorcin and 3 parts of white sugar in 100 parts of alcohol, forms a very delicate test for free HCl when warmed in a dish with the suspected fluid. It is used to detect free HCl in the gastric juice. It gives with HCl a purple red color. The **physiological action** of resorcin is similar to that of phenol, but it is not poisonous. It is given internally as an antiseptic and antipyretic, in doses of two grains, and in some cases as high as 15 grains (1 gram).

Fluorescein or **Resorcin-phtalein,** $C_{20}H_{12}O_5.H_2O$, is also used in medicine, and occurs as dark-brown crystals, which form with ammonia a beautiful red solution with a green fluorescence.

Para-dihydro-phenol, or **Hydroquinone,** $C_6H_4\left\{\begin{matrix}OH(1)\\OH(4)\end{matrix}\right.$, is most easily prepared by passing SO_2 through a warm saturated solution of quinone, $C_6H_4O_2$, when hydroquinone separates in six-sided prisms, fusing at 169° C., and subliming on further heating. It is moderately soluble in water and easily soluble in alcohol and ether. It has been recommended as an antipyretic, antifermentative and antidiarrhœal remedy.

It is claimed that it is harmless, even in large doses. It is given in 5- to 8-grain doses. It is used in photography as a developer, owing to its reducing properties.

Quinone, $C_6H_4=O_2$, is a type of a number of compounds obtained by the oxidation of quite a number of para-benzene derivatives. It is a yellow, crystalline powder, subliming slowly at ordinary temperatures. Nascent hydrogen or reducing agents convert it into hydroquinone.

Orcin—Orcinol—Dihydroxy Toluene, $C_6H_3\,CH_3(OH)_2$—is prepared from certain lichens which furnish **litmus, cudbear** and **archil.** The lichens are boiled with lime and water, the lime precipitated with CO_2, and the orcin extracted with ether. Orcin crystallizes in prisms, has a sweet taste and is soluble in water, alcohol and ether. Orcin forms with ammonia a purple solution, from which acetic acid precipitates **orcein,** the chief coloring matter of litmus, and the other dyes made from lichens, by mixing them with lime and urine and exposing them to the air.

Guaiacol, or **Methyl-pyrocatechin,** $C_6H_4\begin{cases}OCH_3\\OH,\end{cases}$ is a constituent of creasote, of which it constitutes about 60 to 90 per cent.

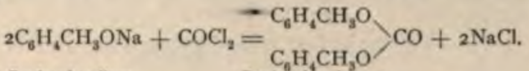
It is prepared by the fractional distillation of beech-wood creasote, collecting that coming over between 200° and 205° C.

It is a liquid having a pleasant odor, and boiling at a little above 206° C. (402.8° F.). Its sp. gr. is 1.133 at 15° C. (59° F.). It is not very soluble in water, requiring 85 parts of water to take up one part of it.

It has been introduced as a remedy in tuberculosis in place of creasote. It is best given in capsules.

Guaiacol Iodide, Guaiacol Carbonate, Guaiacol Carbonic Acid, Cinnamyl guaiacol, and **Guaiacol Salicylate** have been prepared, and proposed for the same purposes as guaiacol.

Of these compounds the **carbonate** is most used. It is prepared by the action of carbonyl chloride on a solution of guaiacol sodium,



$$2C_6H_4CH_3ONa + COCl_2 = \begin{matrix}C_6H_4CH_3O\\C_6H_4CH_3O\end{matrix}\!\!>\!CO + 2NaCl.$$

Guaiacol sodium. Guaiacol carbonate.

The separating crystals are collected and recrystallized from alcohol. It is a white, crystalline powder, nearly free from odor and taste, insoluble in water, and sparingly soluble in alcohol, glycerin and oils. It is decomposed by alkalies into carbonic acid and guaiacol. It is used for the same diseases as guaiacol and creosote.

Benzoyl Guaiacol—Benzosol—$C_6H_4\begin{cases}OCH_3\\OCOC_6H_5\end{cases}$ is a crystalline compound of guaiacol in which the H of the OH group has been replaced by benzoyl. It is prepared first by forming the potassium salt of guaiacol, and warming it with benzoyl chloride, or, by the reaction between guaiacol and benzoic anhydride. Benzosol is a colorless, tasteless, nearly odorless crystalline powder. It is insoluble in water, soluble in hot alcohol, in ether and chloroform. It contains 54 per cent. of guaiacol. It should not melt below 44° C. (111.2° F.).

Guaiacol and its derivatives are not easily oxidized in the body, and are usually partially excreted in the urine, and may be detected in that fluid one-half hour after taking a single dose. It may be detected by distilling the urine with H_2SO_4 (dilute), and adding a drop or two of ferric chloride solution, when, if guaiacol is present, it will give a reddish-brown color. Benzosol is used for the same purpose as guaiacol, and it is decomposed by the alkalies in the same manner as salol.

It is given internally in doses of 4 to 12 grains.

TRIATOMIC PHENOLS.

There are three isomeric trioxy-benzenes: phloroglucin, pyrogallol, and oxyhydroquinone.

Phloroglucin, $C_6H_3(OH)_3$, is obtained by the fusion of potash or soda with various resins and resorcin, or by the action of alkalies upon phloretin. It occurs as large prisms, which dissolve in water, alcohol, and ether, and possesses a very sweet taste. Its solutions give a dark violet color with Fe_2Cl_6. A solution of two parts of phloroglucin and one part of vanillin in thirty of absolute alcohol, is used as a very delicate test for free HCl in gastric juice. It will detect one part of HCl in 20,000 parts of water (Günzburg).

Pyrogallin, Pyrogallol (U. S. P.), or **Pyrogallic Acid,** $C_6H_3\begin{cases}OH\\OH\\OH\end{cases}$. This acid is a trihydro-benzene, and is prepared by heating gallic acid, $C_6H_2(OH)_3CO_2H$, to 300° C. (572° F.). It crystallizes in white, shining needles, and gives a dark-blue color with ferrous, and red with ferric salts. An alkaline solution, when exposed to the air, rapidly absorbs oxygen and assumes a dark color. Silver and gold salts are reduced, in the light, to the metallic state by it; hence it is used as a developer in photography. It has been used in the treatment of skin diseases.

Oxyhydro-quinone, $C_6H_3(OH)_3$, is unimportant.

There are no tetratomic phenols used in medicine. Pentatomic and hexatomic phenols have also been prepared.

Aromatic Alcohols differ from the phenols in constitution. They all contain the group of atoms CH_2OH, and by the oxidation of this group it becomes COOH, carboxyl, with the formation of an aldehyde and an acid, thus:—

$$\underset{\text{Benzylic alcohol.}}{C_6H_5CH_2OH} + O_2 = \underset{\text{Benzoic aldehyde.}}{C_6H_5COH} + O_2 = \underset{\text{Benzoic acid.}}{C_6H_5COOH}.$$

Benzylic Alcohol is formed by distilling benzoic aldehyde with KOH. Its benzoic and cinnamic ethers are found in balsam of Peru and Tolu. It is a colorless liquid of theoretical interest only.

Salicylic Alcohol—Saligenin, $C_6H_4\left\{\begin{matrix}OH\\CH_2OH,\end{matrix}\right.$ is one of the constituents of the natural glucoside, **salicin.** It may be separated from salicin by decomposition with dilute mineral acids, but it is more easily prepared by the action of formaldehyde upon phenol.

$$\underset{\text{Phenol.}}{C_6H_5OH} + \underset{\text{Formaldehyde.}}{HCHO} = \underset{\text{Saligenin.}}{C_6H_4\left\{\begin{matrix}OH\\CH_2OH.\end{matrix}\right.}$$

It has been introduced as a substitute for salicylic acid.

Saligenin crystallizes in colorless leaflets, having a slightly bitter taste. It is fairly soluble in cold, and easily soluble in hot water and in alcohol.

Cynnamyl Alcohol—Styrene, $C_6H_5.CHCHCH_2OH$, occurs as cinnamic ester under the name of styracine in storax (Styrax, U. S. P.).

It forms shining needle-like crystals, having a hyacinth-like odor, and is sparingly soluble in water. On oxidation it gives at first cinnamic acid, $C_6H_5CHCHCOOH$, and then benzoic acid, C_6H_5COOH.

AROMATIC ALDEHYDES.

Benzaldehyde—Oleum Amygdalæ Amaræ (U. S. P.), C_6H_5COH, is a constituent of bitter almond oil, and is a product of the decomposition of **amygdalin,** along with hydrocyanic acid, glucose, and benzoic acid, under the action of the emulsin ferment. It may be prepared by a number of synthetic reactions. It is prepared from the oil, by forming a crystalline solid with sodium bisulphite, separating the crystals, and after dissolving them in water decomposing with a strong solution of Na_2CO_3. It is a colorless, oily liquid with the odor and taste of bitter almonds. Sp. gr. 1.043, and boiling point 179° C. (354.2° F.). Oxidizing agents give benzoic acid, and nascent hydrogen gives benzylic alcohol. When pure it is not poisonous, but the commercial article is seldom free from hydrocyanic acid.

Salicylic Aldehyde — Salicylal — Salicylous Acid, $C_6H_4\left\{\begin{matrix}COH\\OH,\end{matrix}\right.$ or Oil of Spiræ (meadow sweet), is obtained by oxidizing **salicin** with $K_2Cr_2O_7$ and H_2SO_4, and distilling off the aldehyde. It may be prepared synthetically by the action of chloroform and KOH and phenol. Salicylic aldehyde is a colorless fragrant liquid, sp. gr. 1.17, and boiling at 196° C. (384.8° F.). It is sparingly soluble in water, but freely in alcohol. It gives an intense violet color with Fe_2Cl_6

Cinnamic Aldehyde, $C_6H_5CH{=}CHCOH$, is the chief constituent of the oils of cinnamon and cassia. It may be isolated by means of its compound with sodium bisulphite. It has been prepared synthetically. It is a colorless, aromatic oil, boiling at 247° C. (476 6° F.) and oxidizing to cinnamic acid (C_6H_5-$CH{=}CHCOOH$) on exposure to the air.

Cuminic Aldehyde, $C_9H_{11}COH$, occurs in the aromatic oils of cummin, caraway, and water-hemlock.

Anisic Aldehyde, $C_6H_4OCH_3COH$, is obtained as a fragrant oil, by oxidizing the oil of fennel, and the oil of anise with HNO_3.

Vanillic Aldehyde or **Vanillin,** $C_7H_7O_2COH$, is extracted from the pods of the vanilla bean—*Vanilla planifolia*. It is now made synthetically from coniferin, a glucoside found in the bark of trees of the *conifera* family.

AROMATIC KETONES.

The ketones corresponding to the secondary aromatic alcohols may be formed by the same process and have the same properties as those of the methane series.

Phenyl-methyl Ketone—Aceto-phenone—Hypnone, $C_6H_5CO.CH_3$, is prepared by distilling a mixture of molecular proportions of calcium acetate and calcium benzoate: $Ca(C_6H_5$-$COO)_2 + Ca(C_2H_3O_2)_2 = 2CaCO_3 + C_6H_5COCH_3$. It is a colorless, oily liquid with a peculiar odor and pungent taste. It crystallizes at 14° C. (57 2° F.), and melts again at 20.5° C. (69° F). It is slightly soluble in water, but readily miscible with alcohol. It has been used as a hypnotic. Dose, 1 to 3 minims.

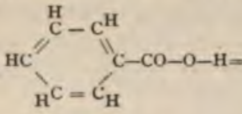
Gallaceto-phenone, $C_2H_3O.C_6H_2(OH)_3$, is a derivative of pyrogallol, containing the radical of acetic acid. It is prepared by the action of pyrogallol upon glacial acetic acid in the presence of zinc chloride. It is a pale-yellow crystalline powder, readily soluble in hot water, and in alcohol and ether. It is soluble in glycerin, but sparingly soluble in cold water.

It has been used as an external remedy in psoriasis.

Phenyl-ethyl Ketone, $C_6H_5COC_2H_5$, **Phenyl-propyl Ketone,** $C_6H_5CO—C_3H_7$, and **Diphenyl Ketone—Benzophenone,** $C_6H_5—CO—C_6H_5$, are also known.

AROMATIC ACIDS.

Benzoic Acid,



$=C_7H_5O_2H$.—This acid occurs in **gum Benzoin,** and in the leaves of the aspen; it is also found in the urine of herbivorous animals. Benzoic acid is prepared from gum benzoin by sublimation. The powdered resin is gently heated in an iron pan covered with a perforated paper cover; over this is placed a paper or felt cone; the benzoic acid is sublimed and collects on the inner surface of the cone. It is also prepared by boiling the resin with milk of lime, filtering, concentrating the filtrate by evaporation, and precipitating the acid with hydrochloric acid. It is also prepared from naphthaline, $C_{10}H_8$, occurring in coal tar, and from hippuric acid found in the urine of cows.

Properties.—Benzoic acid occurs in large, thin, brilliant plates, or needles; it melts at 120° C. (248° F.) and boils at 250° C. (482° F.), but sublimes at a lower temperature. It is soluble in hot water and alcohol, but sparingly soluble in cold water. It has a peculiar, aromatic, irritating odor.

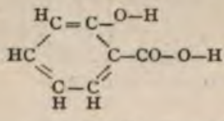
The **benzoates** are generally soluble in water.

The benzoates of ammonium, lithium and sodium are official. The one most used is ammonium benzoate. This salt occurs in colorless and transparent, prismatic crystals or in white and granular crystals, becoming yellow on long exposure to the air. It has a slight odor of the acid, a saline, afterward bitter taste; soluble in 5 parts of water.

The sodium salt is soluble in 1.8 parts of water, has a sweet, astringent taste, is free from bitterness, and has a neutral reaction. The acid and its salts have an antifermentative and antiseptic action. The benzoates may be taken internally without harm. They are eliminated partly unchanged and partly as hippuric acid.

Solutions of benzoates give a flesh-colored or reddish precipitate with ferric chloride.

Salicylic or **Oxybenzoic Acid.**—



$= C_6H_4(OH)CO_2H$

This acid occurrs in the flowers of several species of *spiræa*, and its methyl ether, $C_6H_4\left\{\begin{matrix}OH\\COOCH_3\end{matrix}\right.$, forms a large part of oil of wintergreen, from which it was formerly prepared. It is now prepared on a large scale by passing CO_2 into a heated retort containing sodium carbolate

$$C_6H_5ONa + CO_2 = C_6H_4(OH)CO.ONa$$

and decomposing the mass with hydrochloric acid, to obtain the acid. When pure, salicylic acid occurs as fine, white, prismatic, needle-shaped crystals, permanent in air, having a sweetish, slightly acrid taste and acid reaction; soluble in 450 parts of cold water, and in 2.5 parts of alcohol. Its solutions give an intense violet color with ferric salts. This is used as a test. Salicylic acid is sometimes added to wines, beer, and other articles of food, as a preservative, a use which should be prohibited.

The **salicylates** of potassium, lithium, sodium, bismuth, and some of the alkaloids are used in medicine. The **salicylic esters** are very numerous, some of which are used in medicine, and have already been described.

Closely related to salicylic acid is a glucoside of oxybenzoic alcohol, called **salicin.**

$$C_6H_4\left\{\begin{matrix}OH\\CH_2OH.\end{matrix}\right. \qquad\qquad C_6H_4\left\{\begin{matrix}OH\\CH_2O(C_6H_{11}O_5).\end{matrix}\right.$$

Oxybenzoic alcohol. Salicin.

Salicin is found in the bark of different kinds of willow and poplar, and in castoreum. It is prepared by boiling the bark with water and lead oxide, filtering, precipitating the lead with hydric sulphide, and evaporating down. The salicin separates from the solution in fine, colorless, needle-like prisms, having a very bitter taste and neutral reaction; soluble in 28 parts of water, and in 30 parts of alcohol; insoluble in ether or chloroform; very soluble in hot water. When heated with acids it yields glucose and *seligenin*. It is used in medicine.

Gallic Acid—Tri-oxy-benzoic Acid—$C_6H_2(OH)_3.CO.OH$, is prepared from gall-nuts by keeping them in a warm, moist place until they undergo fermentation, extracting the mass with boiling water and crystallizing. It may be obtained from tannic acid by boiling with diluted acids or alkalies, or by spontaneous fermentation, as above described for gall-nuts.

Gallic acid crystallizes from water in fine, silky needles, readily soluble in three parts of boiling water, in ether and alcohol. It gives a blue-black precipitate with ferric salts, and reduces the salts of silver, mercury and gold. Its normal salts are permanent, but their solutions readily decompose. It has a strong astringent taste, and is used in medicine, in common with tannin, as a hæmostatic and astringent.

Sulpho-carbolic Acid—Ortho-phenyl Sulphonic Acid—$C_6H_4HO.SO_2OH$.—If one part of crystallized carbolic acid be mixed with one part, by weight, of strong sulphuric acid, phenyl-sulphonic or sulpho-carbolic acid is formed.

$$C_6H_5OH + H_2O_2SO_2 = C_6H_4OH.SO_2OH + H_2O.$$

If this solution is diluted with water, and barium carbonate added in excess, a solution of barium sulphocarbolate is produced. From this salt the other salts may be prepared.

The acid is a reddish, viscid liquid, soluble in water. It has antiseptic properties, and may be used internally. It is non-poisonous and non-irritating. The sodium and the zinc salts have been employed in medicine.

Sodii Sulphocarbolas (U. S. P.) is a colorless transparent crystalline solid, with a cooling, saline, slightly bitter taste. It is soluble in 4.8 parts of water and in 132 parts of alcohol. Its solutions give with Fe_2Cl_6 a pale violet color.

Sozoiodol—Di-iodo-para-phenolsulphonic Acid, $C_6H_2I_2OH.SO_2OH$, is a crystalline solid, occurring in acicular prisms, readily soluble in water, alcohol and glycerin.

It is prepared by the action of a solution of iodide and iodate of potassium upon sulphocarbolate of potassium dissolved in dilute HCl. It has been used as a substitute for iodoform in surgical dressings.

Salicyl-sulphonic Acid, $C_6H_3\left\{\begin{array}{l}OH\\COOH\\SO_2OH\end{array}\right.$, is formed by the action of strong sulphuric acid upon salicylic acid. It separates from the mixture as a white, crystalline powder, very soluble in water. It has been used as a very delicate test for albumin in urine, with which it gives, even in dilute solutions, a voluminous coagulum.

ORGANIC BODIES CONTAINING NITROGEN.

Amins. Amids. Imids. Nitrils.

We have frequently spoken in these pages of types of compounds, especially of the water type. We now come to speak of compounds constructed upon the ammonia type.

Ammonia $N\left\{\begin{matrix}H\\H\\H\end{matrix}\right.$ is a type of a large number of organic compounds. An **amin** or amine may be regarded as formed from ammonia by replacing one or more of the H atoms by hydrocarbon radicals. When formed from one molecule of NH_3 they are called **mon-amins**; when from two or three, they are called di-amins and tri-amins respectively.

Primary, secondary and **tertiary amins** are formed by replacing one, two and three atoms of hydrogen respectively. We may represent these different classes of amins as follows:—

MON-AMINS.

	Primary.	Secondary.	Tertiary.
$N\left\{\begin{matrix}H\\H.\\H\end{matrix}\right.$	$N\left\{\begin{matrix}C_2H_5\\H.\\H\end{matrix}\right.$	$N\left\{\begin{matrix}CH_3\\CH_3.\\H\end{matrix}\right.$	$N\left\{\begin{matrix}CH_3\\C_6H_5.\\C_6H_5\end{matrix}\right.$
Ammonia.	Ethylamin.	Dimethylamin.	Methyl-diphenyl-amin.

DI-AMINS.

$N_2\left\{\begin{matrix}H_2\\H_2.\\H_2\end{matrix}\right.$	$N_2\left\{\begin{matrix}C_2H_4''\\H_2.\\H_2\end{matrix}\right.$	$N_2\left\{\begin{matrix}C_6H_4\\C_6H_4.\\H_2\end{matrix}\right.$	$N_2\left\{\begin{matrix}C_2H_4\\C_2H_4.\\(C_2H_5)_2\end{matrix}\right.$
Condensed ammonia.	Ethylene-diamin.	Diphenylene-diamin.	Diethylene-diethyl-diamin.

Amins all have basic properties, and, like NH_3, combine directly with acids to form salts.

Amids may be regarded as formed by replacing the hydrogen atoms in ammonia with negative or acid radicals, as:—

$$\left.\begin{matrix}H\\H\\C_2H_3O\end{matrix}\right\}N.$$

Acetamid.

These bodies are classified and named like the amins. Secondary and tertiary amids, with very few exceptions, are unknown. They differ from the corresponding acids in containing amidogen, NH_2, in place of hydroxyl, OH. Thus:—

$$\underset{\text{Acetic acid.}}{HOC_2H_3O.} \qquad \underset{\text{Carbonic acid.}}{H_2O_2CO.}$$

$$\underset{\text{Acetamid.}}{H_2N—C_2H_3O.} \qquad \underset{\text{Carbamid (urea).}}{(H_2N)_2CO.}$$

Acid Amids or **Amido-acids** are formed by replacing a part of the hydroxyl in a polybasic acid by amidogen, NH_2, thus:—

$$\underset{\text{Carbamic acid.}}{NH_2.HO.CO.} \qquad \underset{\text{Oxamic acid.}}{NH_2HOC_2O_2.}$$

The hydrogen of the amidogen in these compounds may be further replaced by hydrocarbon radicals, thus:—

$$\underset{\text{Phenyl oxamid.}}{N_2H_3\left\{\begin{matrix}C_2O_2\\C_6H_5.\end{matrix}\right.} \qquad \underset{\text{Hippuric acid, or benzamidacetic acid.}}{NH\left\{\begin{matrix}C_2H_2O—O—H\\C_7H_5O.\end{matrix}\right.}$$

Imids differ from the amids in containing the radical NH, where the latter has NH_2, thus:—

$$\underset{\text{Acid carbamid.}}{NH_2CO.OH} — H_2O = \underset{\text{Carbimid.}}{NHCO.}$$

The carbamids are converted by heat into isomeric bodies, which may be regarded as compounds of nitrogen with a triad radical, and known as **nitrils**, thus:—

$$\underset{\text{Diethyl carbamid.}}{N_2\left\{\begin{matrix}(C_2H_5)_2\\H_2\\CO\end{matrix}\right.} \text{ gives } \underset{\text{Propionitril.}}{N\left\{C_3H_5.\right.} H_2O \text{ and } \underset{\text{Ethyl cyanide.}}{CN.C_2H_5.}$$

Amins.—Of the large number of compounds which belong to this class of bodies, we can only mention a few in detail. As before mentioned, the amins are bases, or organic alkalies. They unite directly with acids to form salts, and, with platinic and auric chlorides, to form double salts similar to those formed with ammonia. When heated, amins expel ammonia from its salts. The lower members of the group are gases, while the higher members are liquids or solids.

The amins containing the lower alcohol radicals bear the closest resemblance to NH_3, but are more strongly alkaline. In some cases they are caustic. They have an ammoniacal odor. They combine directly with acids, like NH_3, to form salts. They

[illegible]

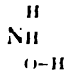
[illegible]

[illegible]

[illegible] a series [illegible] ... [illegible] we have the following:

[illegible]

[illegible] be decomposed [illegible] ethyl in the [illegible] a series of amins, [illegible] C_2H_5 takes the place of CH_3. Numerous isomers [illegible] among the amin bases. When combined with acids, amins behave like NH_3, the ammonium bases like NH_4OH. The salts thus obtained are white, crystalline, frequently hygroscopic compounds, easily soluble in water. The chlorides form double salts with $PtCl_4$, similar to $2NH_4Cl.PtCl_4$.



NH_3O or $N\begin{matrix}H\\H\\O-H\end{matrix}$

Hydroxyl Amin, (NH_3O or $NH\ldots$).—This compound, closely related to ammonia, may be regarded as a molecule of ammonia in which one hydrogen atom has been replaced by the hydroxyl radical. It is prepared by treating tin with diluted nitric acid, or a mixture of this and hydrochloric acid. The nascent hydrogen generated reduces the acid, and forms the above compound, which combines directly with the remaining free acid.

$$HNO_3 + 3H_2 = H_3NO + 2H_2O.$$

It is an unstable liquid, not obtainable in a free state, and possesses decided basic properties—*i. e.*, it colors red litmus paper blue, and combines directly with acids to form salts.

$$\underset{\text{Hydroxyl amin.}}{H_3NO} + HCl = \underset{\text{Hydrochlorate of hydroxyl amin.}}{NH_2OH,HCl.}$$

The hydrochlorate has been used as a local application in certain skin diseases, such as psoriasis, lupus, etc.

Methylamin, NH_2CH_3, occurs in certain plants (*Mercurialis perennis*), in the distillate from bones and wood, and in herring brine. It is formed in many decompositions of nitrogenous bodies. It is more strongly basic than NH_3. It has a powerful ammoniacal odor, is soluble in water, and its solution behaves with metals like NH_4OH. It is a colorless, inflammable gas. One volume of water dissolves 1154 volumes of the gas. It forms a well-defined series of methylamin salts with the acids, which are generally crystallizable and soluble in water.

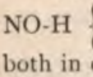
Dimethylamin, $NH(CH_3)_2$, occurs in Peruvian guano and pyroligneous acid.

Trimethylamin, $N(CH_3)_3$, is pretty widely distributed in nature, is found in herring brine, chenopodium, arnica flowers, and the blossom of the pear. It also occurs naturally in cod-liver oil, guano, human urine, in ergot and many flowers. It may be prepared by the action of potassium hydrate on many of the vegetable substances, such as alkaloids, etc. It is an oily liquid, having a disagreeable odor, is strongly alkaline, soluble in water, alcohol, and ether. It combines with acids to form crystallizable salts. These three methylamins, above described, are produced by the putrefactive decomposition of animal matters, being accompanied by smaller quantities of other amins, and peculiar alkaloids known as ptomaines. It has been discovered in the residue from the evaporation of water contaminated with sewage. Trimethylamin occurs in yeast, and is frequently obtained by the distillation of distillery waste.

Propylamin, $NH_2C_3H_7$, is a colorless liquid, boiling at 50° C. (122° F.). Its hydrochlorate has been used in medicine.

Tetramethylammonium Hydroxide, $NOH(CH_3)_4$. This compound is obtained by decomposing the corresponding iodide, $NI(CH_3)_4$. It is a crystalline solid, very soluble in water, a strongly caustic alkali resembling ammonium hydroxide. It forms crystallizable salts with acids.

Cholin, Trimethyl-oxethyl-ammonium Hydroxide, $NOH(CH_3)_3(C_2H_5O)$, occurs in combination in the human body, in the complex substance known as lecithin. It was first discovered among the decomposition products of the bile. It is a colorless fluid of oily consistency, possesses a strong alkaline reaction, and forms deliquescent salts with acids. The salts with HCl, $PtCl_4$ and $AuCl_3$ are the most important. Cholin is a most unstable body, the mere heating of its aqueous solution sufficing to split it up into glycol, trimethylamin, and ethylene oxide. It may be prepared from the yolk of eggs by decomposing the residue of the yolk left after complete extraction of the substance with alcohol, by boiling it for an hour with BaO_2H_2. The Ba compound is decomposed with CO_2 and the cholin precipitated from this solution with $PtCl_4$. By oxidation with nitric acid it yields an extremely poisonous alkaloid, **muscarin,** $C_5H_{15}NO_3$. Cholin itself is more or less poisonous, and is now recognized as one of the ptomaïnes which occur in putrefying animal matters.

Neurin, Tri-methyl-vinyl-ammonium Hydroxide,  $NO\text{-}H \begin{cases} (CH_3)_3 \\ C_2H_3 \end{cases}$.—This substance is closely related to cholin both in composition and origin. It is a decomposition product of lecithin and protagon, and is formed by the putrefactive decomposition of animal tissues. It is one of the alkaloidal bodies known under the name of ptomaïne. It is, like cholin, a syrupy fluid with a strong alkaline reaction, and is extremely soluble in water. It forms double salts with platinum and gold, similar to those of cholin. Neurin is a much more powerful poison than cholin.

Muscarin, $NOH(CH_3)_3C_2H_3O\ H_2O$, is closely related to cholin and neurin. It occurs in the poisonous mushroom, *Agaricus muscarius*, and is produced during the putrefactive decomposition of albuminoid substances. The free alkaloid occurs in very deliquescent crystals, colorless, odorless, tasteless, and strongly alkaline. It it soluble in water and alcohol in all proportions, sparingly soluble in chloroform, and insoluble in ether. It is a more powerful base than ammonium hydroxide, and forms a series of salts. Like cholin and neurin, it is a very active poison. The symptoms of muscarin poisoning are salivation, vomiting and diarrhœa, contraction of the pupils, diminution of the rapidity of the pulse, interference with respiration and locomotion, gradual depression of the heart's action, and finally death. Atropine is physiologically antagonistic to muscarin and diminishes its intensity of action.

Phenylamin, or **Anilin,** $NH_2C_6H_5$, is the best known amin. It is obtained from benzene by first converting this into nitrobenzene, by the action of concentrated nitric acid.

$$C_6H_6 + HNO_3 = C_6H_5NO_2 + H_2O.$$

Nitro-benzene is generally a brown or pale yellow, strongly refractive liquid, boiling at 220°C. (428° F.); it has a burning, sweet taste, and an odor resembling that of bitter almonds and cinnamon. It is used in perfumery under the name of **essence of mirbane.** It is a violent poison. When treated with nascent hydrogen, generated by zinc and sulphuric or hydrochloric acid, **anilin** is produced.

$$\underset{\text{Nitrobenzene.}}{C_6H_5NO_2} + 3H_2 = \underset{\text{Anilin.}}{C_6H_5NH_2} + 2H_2O.$$

The anilin combines with the acid present, forming crystallizable salts. Like all the amins, it acts as a base, uniting directly with acids.

Anilin is, when pure, a colorless, oily, refractive liquid, boiling at 182° C. (359° F.), and is insoluble in water. It is the basis of a large number of beautiful coloring matters, very much employed in dyeing and calico printing. In 1858, Perkins obtained a purple dye, by acting upon anilin oil with potassium dichromate and sulphuric acid. Other colors were soon obtained; greens, yellows, reds, blues, violets, and black have all been obtained from anilin. These dyes are soluble in alcohol and glycerin, and are used for a variety of purposes. They are not very permanent.

Anilin is easily detected by the addition of a solution of sodium hypochlorite (chlorinated soda), with which it gives a purple-colored solution. Anilin is a powerful antiseptic, especially in its action on the tubercular bacillus.

Anilin is a powerful narcotic poison, whether taken internally, or inhaled as a vapor. The salts, when pure, are comparatively innocuous.

Diamins.—Few of the diamins known are of importance to the physician or pharmacist. Some of them have been discovered among the products of the putrefaction of albuminoid substances, and it is quite probable that some of the natural vegetable alkaloids belong to this class of bodies.

Piperazine—Di-ethylene-diamin, $N_2 \left\{ \begin{matrix} H_2 \\ (C_2H_4)_2 \end{matrix} \right. = C_4H_{10}N_2$.—This is a synthetical compound recently introduced as a solvent for uric acid. It is prepared by the action of ammonia on ethylene bromide or chloride.

The reaction is complex, giving salts of a number of bases. When this product is distilled, it yields a distillate between 130° C. and 180° C. (266° F. to 356° F.) from which diethylene-diamin separates.

It is isolated by forming a dinitroso piperazine by the action of a nitrite. This product, when treated with HCl, evolves nitrous acid and hydrochlorate of piperazine.

Piperazine is a white, lustrous, crystalline solid, melting at 104 to 107° C. (219.2° F. to 224.6° F.) and boiling at 145° C. (293° F.).

It is very soluble in water. It absorbs water and CO_2 from the air and becomes liquefied. The aqueous solution is nearly tasteless and has a strong alkaline reaction.

The compound which it forms with uric acid is 17 times more soluble than lithium urate, it being soluble in 50 parts of water. It is not decomposed in the body, and is excreted in the urine as a neutral urate.

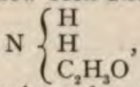
The **amids** differ from the amins in having an acid radical where an amin has a hydrocarbon radical. They may be primary, secondary, or tertiary. They may be mon-amids, di-amids, or tri-amids. The primary mon-amids containing radicals of the fatty acid series are solid, crystallizable bodies, neutral in reaction, volatile without decomposition, and are usually soluble in alcohol and ether. They unite with acids to form salts. They also unite with certain alkaline hydroxides to form metallic salts.

Formamid, NH_2CHO, is a colorless liquid, soluble in water and alcohol, boiling at 192° C. (377.6° F.) with partial decomposition. It is prepared by heating ethyl formate with an alcoholic solution of ammonia or by the dry distillation of ammonium formate. It combines with chloral to form a compound which has been introduced into medicine as a hypnotic under the name of **chloralamid.**

Chloralamid—Chloral-formamid—$NH \left\{ \begin{matrix} CHO \\ CCl_3CH_2O \end{matrix} \right.$. It occurs in the form of colorless, odorless, faintly bitter crystals, fusing at 115° C. (239° F.), and is sparingly soluble in water.

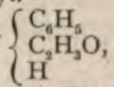
It requires about 20 parts of cold water, or 1½ parts of 96 per cent. alcohol, to dissolve one part of the substance. Hot water decomposes it into chloral hydrate and ammonium formate. The same effect is produced by alkalies, but not by diluted acids. It is employed as a hypnotic in from 10 to 40 gr. doses.

Chloralimid, $NH.CCl_3CH$, is a compound closely related to chloralamid. It is formed by the action of ammonium acetate upon chloral hydrate, or by the action of heat upon chloral ammonium. It is a crystalline solid, sparingly soluble in water, readily soluble in ether, alcohol, and in the fatty oils. When heated to about 180° C. (356° F.) it decomposes into chloroform and formamid. It is very stable, being unaffected by light, air, or moisture. It has been employed in medicine as a hypnotic, but has now been discarded.


Acetamid, $N\left\{\begin{matrix}H\\H\\C_2H_3O\end{matrix}\right.$, is obtained by heating ethylacetate and aqua ammonia, and purifying by distillation. It is a solid, crystalline substance, very soluble in water, alcohol, and ether. Strong alkalies decompose it into ammonia and the acetates of the alkaline metals.

DERIVATIVES OF ANILIN.

The remaining H atoms of the original ammonia, from which anilin is supposed to be derived, may be replaced by a considerable number of radicals. We may substitute Cl for the H, forming several isomeric chlor-anilins. In all such cases the N is assumed to be attached to C atom number one of the benzene ring. A large number of isomeric compounds are thus produced, none of which have been employed in medicine. The nitro derivatives, which may easily be formed, are not employed in medicine. The anilids may be considered as a class of compounds in which one or more of the remaining H atoms in NH_3 have been replaced by an acid radical. They may also be regarded as amids, a part of whose remaining H of the amidogen group has been replaced by phenyl.


Acetanilid—Antifebrin—$N\left\{\begin{matrix}C_6H_5\\C_2H_3O\\H\end{matrix}\right.$, differs from anilin in having the radical of acetic acid substituted for one hydrogen atom. It is prepared by the distillation of anilin acetate, or by boiling anilin with glacial acetic acid.

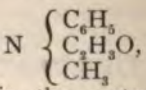
It occurs in white, shining plates, melting at 112.8° C. (235° F.), and boiling at 292° C. (558° F.).

It is sparingly soluble in cold water, but is more freely soluble in hot water, from which it crystallizes on cooling. It is very much employed in medicine as an antipyretic, *i e.*, to lower the bodily temperature in fevers. It is used in the arts for the preparation of derivatives of anilin.

It is prepared by the prolonged action of pure anilin upon glacial acetic acid at a high temperature, submitting the mixture to fractional distillation, collecting what passes over at 295° C. (563° F.), and recrystallizing from boiling water.

$$\underset{\text{Anilin.}}{C_6H_5NH_2} + \underset{\text{Acetic acid.}}{C_2H_3O_2H} = \underset{\text{Acetic anilin.}}{C_6H_5NHC_2H_3O} + H_2O.$$

It is official in the U. S. P. and in several foreign countries. It is identified by the development of a yellow-green color with a green efflorescence (flavanilin) when heated for some time with an equal weight of $ZnCl_2$. Acetanilid is only partly decomposed in the animal body, being excreted in the urine in the form of complex phenols. **Antifebrin** is the copyright name of acetanilid.



Methyl-acetanilid — Exalgin, $N\begin{cases}C_6H_5\\C_2H_3O\\CH_3\end{cases}$ is produced by the substitution of CH_3 for H in the acetanilid. It is formed by the action of methyl iodide, CH_3I, upon sodium acetanilid. It occurs as a tasteless, crystalline powder, with a melting point of 100° C. (212° F.), and boiling without decomposition at 240° to 250° C. (464° to 482° F.). It is readily soluble in alcohol, but with difficulty in water. It is employed in medicine for the relief of pain, and is best given in capsules or powders.

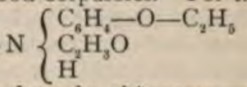
Hydrazins.—The hydrazins are a series of peculiar bases, mostly liquid and closely resembling the amins. They differ from them in containing two atoms of N instead of one, and in their ability to reduce an alkaline copper solution (Fehling's) in most cases even in the cold. They are derived from diamidogen or hydrazin, NH_2NH_2, of which little is yet known. In hydrazin, as in ammonia, we may replace one or more of the H atoms with a hydrocarbon radical. If one H atom be replaced, we have a primary hydrazin; if two are replaced, we have a secondary hydrazin.

Thus **Ethylhydrazin,** $C_2H_5NH{-}NH_2$, is a primary hydrazin. **Diethyl hydrazin,** $(C_2H_5)_2{=}N{-}NH_2$, is a secondary hydrazin.

Phenylhydrazin, $C_6H_5NH—NH_2$, is a colorless, crystalline solid, melting at 23° C. (73° F.) to a colorless oil which boils at 233° C. (451° F.) without decomposition. It combines with HCl to form phenylhydrazin hydrochlorate, $C_6H_5N_2H_3HCl$, which forms white, crystalline plates. Like all hydrazins, it is characterized by its strong reducing power, reducing Fehling's solution in the cold. It is prepared by reducing diazo-benzene chloride with $SnCl_2$ and HCl. It is sparingly soluble in water, but soluble in alcohol and ether. It is important as an exceedingly delicate test for aldehydes and ketones, combining with them to form a class of bodies known as **hydrazones**, and with the sugars to form **osazones.** Most of these compounds are solid and crystalline, and may easily be recognized. They are employed in the separation of the sugar from one another. (See pages 362–366.

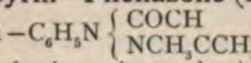
Hydracetin — Pyrodin — Acetyl-phenyl-hydrazin — $C_6H_5NHNHCH_3CO$, is prepared by heating phenylhydrazin and acetic anhydride, dissolving the product in boiling water and crystallizing. It is also prepared by the prolonged action of glacial acetic acid on phenylhydrazin, distilling with an excess of acid and crystallizing. It occurs as a white, tasteless odorless, crystalline powder, melting at 128° C. (262.4° F.) and soluble in 50 parts of water. When boiled with HCl it splits up into acetic acid and phenylhydrazin hydrochlorate. Like phenacetin and methacetin, it forms a colorless solution with H_2SO_4, which turns red on the addition of HNO_3. It is a strong reducing agent, reducing silver nitrate, $AgNO_3$, and gold chloride, $AuCl_3$, precipitating the metals. It has been recommended as an antipyretic and for external use in skin diseases. It is a well-marked blood poison, destroying the blood corpuscles. For this reason care must be exercised in its use.

Phenacetin — Acetphenetidin —



$$N\begin{cases} C_6H_4—O—C_2H_5 \\ C_2H_3O \\ H \end{cases}$$

As will be seen from a comparison of the formulæ, this compound is closely related to acetanilid. It is prepared from sodium para-nitro-phenol by converting it into para-nitro-phenetol by the action of ethyl iodide. This is reduced to paraphenetidin, which on prolonged boiling with glacial acetic acid, yields phenacetin. Phenacetin occurs as colorless, tasteless, inodorous, glistening, scaly crystals, melting at 135° C. (275° F). It is sparingly soluble in cold water, but soluble in about 70 parts of hot water. It is more soluble in alcohol. It is very much employed in medicine as an antipyretic, and for the relief of pain, in doses up to 15 grs. It has slight, if any, toxic properties. It may be identified by the production of a deep red color with chromic acid, when added to the drug dissolved in diluted hydrochloric acid. Its freedom from acetanilid may be proven if its aqueous solution does not become turbid on the addition of Br. water. Sulphuric acid should dissolve it without color. Heated with free access of air, it burns off, leaving no residue.

Antipyrin—Phenazone (B. P.)—**Phenyl-dimethyl-pyrazolon**— $C_6H_5N\left\{\begin{matrix}COCH\\NCH_3CCH_3\end{matrix}\right.$, is prepared by the action of phenylhydrazin and acetylactic acid by which phenylhydrazin acetylactate is formed. By the action of heat, this separates into ethyl alcohol and phenyl-methyl-pyrazolon. By warming this compound with methyl iodide, a dimethyl phenylpyrazolon is produced. Antipyrin forms small, lustrous, rhombic needles, or plates, which are odorless and have a bitter taste. It melts at 113° C. (235° F.), and is readily soluble in water, alcohol and chloroform, but is less soluble in ether. On exposure to the air it takes up a small quantity of water and thus melts at a lower temperature. It is decomposed by strong NaOH solution, the base separating as a milky oil speedily collecting into oil globules. The aqueous solution exhibits no alkaline reaction with litmus paper, but does so with methyl orange. It may be quantitatively estimated by titration in an aqueous or alcoholic solution with methyl orange as an indicator. It is a strong univalent base. Its salts, most of which are soluble, do not crystallize. Several of these salts have been used in medicine. The benzoate, obtained by the addition of antipyrin to a boiling solution of benzoic acid, has a pungent taste and slight odor of benzoic acid. It is slightly soluble in water, but freely so in alcohol and ether The salicylate, or **salipyrin,** is the only one of these salts which has been much used in medicine. It is prepared by the direct combination of antipyrin and salicylic acid. It occurs as a white, coarsely crystallized, odorless powder, with a harsh sweetish taste, almost insoluble in water, but readily soluble in alcohol, from which it crystallizes in hexagonal tables. It has been recommended as a remedy in the treatment of rheumatism It also forms compounds with phenol. **Phenopyrin** is prepared from equal parts of crystallized phenol and antipyrin. **Pyrogallopyrin, naphthopyrin** and **resopyrin** are compounds of pyrogallic acid, naphthol, and resorcin, respectively, with antipyrin. Antipyrin forms several compounds with chloral. One of these has been used in medicine under the name of **hypnal.** **Iodopyrin** is a substitution product of antipyrin, in which one atom of H of the benzene nucleus has been replaced by iodine. The formula is $C_6H_4I—N\left\{\begin{matrix}COCH\\NCH_3CCH_3\end{matrix}\right.$. It occurs as a tasteless, colorless, crystalline powder. It is slightly soluble in cold, and readily in hot water.

Tests.—Antipyrin gives a delicate and characteristic blood-red coloration with Fe_2Cl_6. The reaction is distinct in a solution of 1 in 2000. The red color is discharged by HCl. This reaction is given at once by urine containing antipyrin. On cautiously adding a solution of iodine in potassium iodide to a solution of antipyrin, a permanent brick-red precipitate is produced, perceptible in a solution containing 1 part in 20,000. Antipyrin gives a white precipitate with Millon's reagent. When heated with strong HNO_3 until reaction commences, and the liquid then allowed to cool, a purple color is produced. On adding water a violet precipitate is thrown down. This reaction is probably due to the formation of nitrous acid, which gives with antipyrin a beautiful green coloration, perceptible in 1 part in 20,000. When the liquid is heated it becomes purple-red. In strong solutions, small green needle-shaped crystals occur. These consist of **iso-nitroso antipyrin,** $C_{11}H_{11}N_3O_2$. **Nitroso antipyrin** explodes when heated to about 200° C. (392° F.). It is said to be poisonous. A green coloration of antipyrin with nitrous acid thus becomes a delicate test, but is common to all pyrazolons. With spirit of nitrous ether, antipyrin rapidly acquires a dark-green color, and green needles of nitroso antipyrin, separate. This green compound has been claimed to be poisonous, but experiments upon rabbits and dogs seem to show that 4 grains produce no perceptible poisonous effects. From the variety of reactions which antipyrin may undergo, there are a considerable number of medicines which are incompatible with it. It should, therefore, generally be given by itself, and not mixed with other substances.

AMIDO-ACIDS, OR ACID AMIDS, AND THEIR DERIVATIVES.

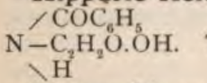
These compounds may be regarded as amids formed by replacing a part of the hydrogen of a radical of an organic acid with amidogen. They exhibit both acid and basic properties. Many of these compounds and their derivatives exist in the human body. The simplest representative of the amido-acids is **Glycocol—Glycocin,** or **Amido-acetic Acid**—$N\left\{\begin{matrix}H_2\\CH_2COOH.\end{matrix}\right.$ It is prepared by heating monochloracetic acid with ammonia,

$$CH_2ClCO_2H + 2NH_3 = CH_2NH_2COOH + NH_4Cl,$$

or boiling glue with alkalies or acids. H_2SO_4 is added to the mass to separate the alkali as a sulphate. It is then evaporated to dryness, and the residue exhausted with alcohol and allowed to crystallize. It may also be prepared from ox bile and from uric acid, or by the action of formaldehyde upon a solution of hydrocyanic acid. $CH_2O + HCN + H_2O = NH_2CH_2COOH$. It appears as large, colorless, transparent crystals, having a sweet taste and melting at 170° C. (338° F.) and decomposing at higher temperatures. It is sparingly soluble in cold water, but more soluble in warm. It is insoluble in alcohol and ether and has an acid reaction. It combines with acids to form crystalline salts, which are generally decomposed by boiling water or by treatment with strong acids. When heated under pressure with benzoic acid, it forms hippuric acid. Its acid function is more marked than its basic. It expels carbonic and acetic acids from many of their salts. With ferric chloride, Fe_2Cl_6, it gives an intense red colored solution, discharged by acids and returning on neutralization. With phenol and NaOH solution, it gives a blue color similar to that given by ammonia. It gives a characteristic copper salt like most of the amido-acids. This salt serves for the separation of these acids.

Glycocol does not occur in the free state in the animal body, but enters into the composition of several important substances, more especially hippuric and glycocholic acids. It exists in combination in the gelatins, and with cholic acid as sodium glycocholate in the bile.

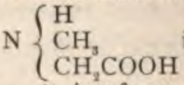
Hippuric Acid—Benzamidacetic Acid—



$$N \begin{cases} COC_6H_5 \\ C_2H_2O.OH \\ H \end{cases}$$

This acid is found in the urine of herbivorous animals, and in small quantity in human urine. When benzoic acid or oil of bitter almonds is taken internally, hippuric acid appears in the urine. It is generally prepared by evaporating the urine of the cow or horse to one-tenth its volume, and precipitating with hydrochloric acid. It forms large, rhombic prisms, soluble in hot, but sparingly in cold water; soluble in alcohol, but not in ether. The hippurates resemble the benzoates.

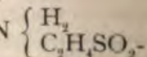
Methyl-glycocol—Sarcosin,



$$N \begin{cases} H \\ CH_3 \\ CH_2COOH \end{cases}$$

is found only in combination in the human body. It is of some interest as having been employed in experiments to determine the origin of urea in the body. It combines with cyanamid to form creatin. It, therefore, enters into the composition of creatin.

Taurin — Amido-ethyl-sulphonic Acid—

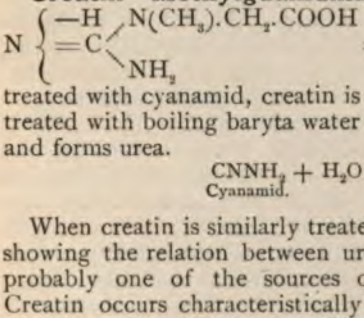


$$N \begin{cases} H_2 \\ C_2H_4SO_2\text{-}OH \end{cases}$$

occurs in traces in the juice of muscles and of the lung.

It is known chiefly as a constituent of taurocholic acid, one of the characteristic biliary acids, especially of the carnivora. It crystallizes in colorless, four or six-sided prisms. It is readily soluble in water, less so in alcohol. Its solutions are neutral. It is a very stable compound, resisting a temperature of less than 240° C. (464° F.), and is not decomposed by diluted alkalies or acids even on boiling. The metallic salts do not precipitate it. It may be prepared from ox bile by boiling for several hours with diluted HCl. A resinous scum separates, and the bile acids are then precipitated from the liquid with lead acetate, the excess of lead being removed with H_2S. The filtrate from the PbS is concentrated and set aside to crystallize. It is purified by recrystallization. When taurin is introduced into the alimentary canal, the larger part appears in the urine in combination with carbamic acid as tauro-carbamic acid. When injected subcutaneously, it is largely excreted in an unaltered form.

Creatin—Methylguanidinacetic Acid—



$$N\left\{\begin{array}{l}-H \\ =C\begin{array}{l}\diagup N(CH_3).CH_2.COOH \\ \diagdown NH_2\end{array}\end{array}\right. = C_4H_9N_3O_2.$$

—When sarcosin is treated with cyanamid, creatin is produced. When cyanamid is treated with boiling baryta water it takes up a molecule of water and forms urea.

$$\underset{\text{Cyanamid.}}{CNNH_2} + H_2O = \underset{\text{Urea.}}{CO(NH_2)_2}.$$

When creatin is similarly treated, it yields sarcosin and urea, showing the relation between urea and creatin, which body is probably one of the sources of urea in the human body. Creatin occurs characteristically in the muscles and hence in meat extracts. The amount is variable, but may be taken as from 0.2 to 0.3 per cent. of the weight of the muscle. It is also found in nervous tissues and in several other tissues of the body. It may also be found in the urine, where it is believed to be derived from creatinin. Creatin, when pure, occurs in white, opaque, colorless, transparent crystals. It is soluble in 75 parts of water, slightly soluble in alcohol, and insoluble in ether. Its solutions are neutral in reaction. Creatin is a weak base, forming crystalline compounds with some of the acids. It is most easily prepared from extract of beef which is dissolved in water, precipitated with basic acetate of lead, filtered, and the lead separated from the filtrate with H_2S, concentrated at a moderate temperature to a syrup, and set aside to crystallize. As stated above, creatin may easily be derived from creatinin, and the reverse. Creatin very readily loses a molecule of H_2O, and thus becomes **Creatinin,** $C_4H_7N_3O$. It occurs normally as a constant constituent of the urine, varying in amount from 0.5 to 4.9 grms. per day, according to the amount of meat eaten. It crystallizes in colorless prisms or tables according to the condition in which it is crystallized. It frequently assumes the peculiar whetstone shape of uric acid crystals. It is readily soluble in cold water, and alcohol, but is scarcely soluble in ether. Its solutions are usually alkaline, and it acts as a powerful base, forming compounds with the acids and salts which crystallize well. It is precipitated from its solutions with $ZnCl_2$, in the form of a crystalline precipitate or warty lumps of aggregated crystals. This compound is formed whenever the solutions are brought together in a neutral and somewhat concentrated form. The addition of alcohol to the solution renders the precipitate more complete. This compound with $ZnCl_2$ is employed as a characteristic test for creatinin.

Leucin—Amido-caproic Acid,—$C_6H_{13}NO_2$, is a product of the decomposition of proteids and gelatin by either boiling acids, caustic alkalies, pancreatic digestion, or putrefactive fermentation. It occurs normally in variable amounts in the pancreas, spleen, thymus, thyroid, liver, and salivary glands, also in plants, such as bulbs, tubers, and seeds, where reserved material is stored. It is most easily prepared by the pancreatic digestion of proteids, when it is produced in quantities of from 8 to 10 per cent. of the proteid digested, and is then always accompanied by tyrosin. It sometimes occurs in the urine, particularly in cases of acute yellow atrophy of the liver, although it does not always occur in this disease. Leucin forms yellow brown spheres consisting of masses of needle-shaped crystals, soluble in water, slightly soluble in alcohol, and insoluble in ether. Under the microscope the spheres resemble fat globules. When pure it forms very thin, white, glistening crystals. Leucin is very soluble in the presence of acids and alkalies, the acid solution being lævorotatory, the alkaline solution being dextrorotatory. When heated, leucin decomposes into CO_2 and amylamin,

$$C_6H_{13}NO_2 = CO_2 + C_5H_{11}NH_2.$$

With HI it gives caproic acid and ammonia,

$$C_6H_{13}NO_2 + 2HI = C_6H_{12}O_2 + NH_3 + I_2.$$

With H_2SO_4 it gives ammonia, NH_3, and valerianic acid. With potassium permanganate it gives oxalic acid, carbonic acid, valerianic acid, and ammonia. It is probable that similar decompositions occur in the human body. It is probably one of the intermediate products in the formation of urea.

Tyrosin -- Amido-oxy-phenyl-propionic Acid. — Propionic acid has the formula $C_3H_6O_2$. Amido-propionic acid has the formula $C_3H_5NH_2O_2$. Oxy-propionic acid has the formula $C_3H_5(C_6H_4OH)O_2$. If another H in this formula be replaced by NH_2 we get $OH.C_2H_3(NH_2)COOH$, which is the formula of **tyrosin.** Tyrosin always accompanies leucin, though in less amount, as a product of the pancreatic digestion of proteids, but not of gelatin. It is also a product of the putrefactive decomposition of proteids and gelatin, as well as of the action of boiling mineral acids and alkalies. It is found normally in the pancreas and some other tissues. It occurs in the urine, together with leucin, in phosphorus poisoning, and certain diseases of the liver, especially in yellow atrophy. It is also present, along with leucin, in many plant tissues. Tyrosin crystallizes in very fine needles, usually collected together in feathery masses. The crystals are colorless, tasteless, and odorless. They are sparingly soluble in cold water, almost insoluble in alcohol, and quite insoluble in ether. They are readily soluble in acids and alkalies. It may be obtained, along with leucin, by boiling horn shavings with H_2SO_4 (5 of acid to 13 of water). The H_2SO_4 is separated with lime, and the filtrate from the $CaSO_4$ evaporated down and crystallized. It is purified by recrystallizing from boiling water. It is separated from leucin by repeated crystallization, taking advantage of the great solubility of leucin and the slight solubility of tyrosin. When heated with Millon's reagent, tyrosin yields a brilliant crimson or pink coloration. If moistened on a watch glass with strong H_2SO_4 and warmed for five or ten minutes on a water-bath, it forms tyrosin sulphonic acid and turns pink.

Cystin—Amido-sulpho-lactic Acid.—$C_3H_7NSO_3 = C_3H_4(HS)(NH_2)O_3$.—It is a constituent of rare urinary calculi occurring in men and dogs. It may also occur in renal concretions. It is occasionally found in the urine, from which it separates as a sediment on standing. It is prepared from this sediment, or from a cystic calculus, by solution in ammonia and crystallizing. It crystallizes in regular six sided tables, characteristic in appearance. It is insoluble in ether, alcohol, and water, but is readily soluble in NH_4OH. When boiled with NaOH, a sulphide of sodium is obtained which gives a dark stain on silver coin.

Aspartic Acid, $C_4H_7NO_4$, is **amido-succinic acid.** It is obtained from asparagin which occurs in plants.

Glutamic Acid, $C_5H_9NO_4$, is **amido-glutaric acid.**

Carbamic Acid, or **amido-formic acid,** $NH_2CO.OH$, is not known in the free state. These three acids are products of the decomposition of proteids. Carbamic acid is of interest on account of the important part it is supposed to play in the formation of urea in the animal body. It may be formed by the direct union of dry NH_3 and CO_2, a second molecule of NH_3 uniting with it at the same time to form the ammonium carbamate, thus:

$$2NH_3 + CO_2 = \underset{\text{Ammonium carbamate.}}{NH_4(CO_2NH_2)}.$$

By simple dehydration this salt yields urea,

$$NH_4NH_2CO_2 = H_2O. + \underset{\text{Urea.}}{(NH_2)_2CO}.$$

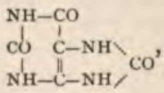
Ammonium Carbamate is extremely soluble in water, in which solution it is gradually converted into the carbonate. When it is heated to 60° C. (140° F.), it decomposes into NH_3 and CO_2; but when heated under pressure at 130° to 140° C. (266° to 284° F.), it yields urea.

Urea—Carbamid—$(NH_2)_2CO$, is the chief nitrogenous constituent of urine. The urine of birds contains a small quantity. When on a meat diet the average normal human urine contains from 2.5 to 3.5 per cent., the average daily excretion being about 30 grms. It is also found in minute quantities in normal blood, serous fluids, lymph, perspiration, and the aqueous humor. It is also met with in the liver. It crystallizes from a concentrated solution in the form of long, thin, glittering, needle-shaped crystals. If deposited slowly, it forms four-sided prisms with pyramidal ends They are anhydrous Urea is very soluble in cold water, less soluble in alcohol, and insoluble in pure ether and petroleum ether. It possesses a somewhat bitter, cooling taste, resembling that of saltpetre. It may be prepared from the urine by concentrating to a syrup, extracting the residue with boiling alcohol, and concentrating the alcoholic extract by slow, spontaneous evaporation, until the urea crystallizes out. It is then purified by recrystallization from alcohol, decolorizing with charcoal if necessary. Or the urea may be precipitated as nitrate by the addition of nitric acid to the concentrated and cooled urine. The nitrate is then decomposed by suspending it in water and adding barium carbonate. The urea is then crystallized as before. It may be prepared synthetically in several ways. The most convenient method is by mixing equal quantities of ammonium sulphate and potassium cyanate, The ammonium cyanate thus formed, on being evaporated to dryness, is transformed into urea, $NH_4CON = NH_2CONH_2$. This synthesis was performed by Wöhler in 1828, and was the first substance of animal origin that was artificially prepared, and may be regarded as the beginning of synthetic chemistry. Urea forms well-defined salts with both bases and acids. The nitrate, $(NH_2)_2CO.HNO_3$, is easily obtained from urine by evaporating it down to about one-fourth its volume, adding pure nitric acid, and keeping the solution cool. The crystals will separate in a few minutes in the form of rhombic tables, frequently aggregated into masses. The crystals are only slightly soluble in HNO_3 or alcohol, but are soluble in water. The oxylate of urea crystallizes out in rhombic tables, closely resembling those of the nitrate, and under the same conditions. Of the many salts which urea forms with bases and salts, that which it forms with mercuric nitrate is important, because this salt is used as a reagent for the quantitative estimation of urea. When a solution of mercuric nitrate is added to one of urea, a precipitate is formed as long as urea remains in solution. Urea may be heated dry at about 120° C. (248° F.) without decomposing, but at about 132.6° C. (271° F.) it gives off ammonia, and at 150° C. (302° F.) it is converted largely into biuret. $2(NH_2)_2CO = NH_2CONHCONH_2 + NH_3$. On heating to a higher temperature (about 200° C. (392° F.)) it is largely converted into cyanuric acid. When boiled in water with strong H_2SO_4 or alkalies, it gradually absorbs two molecules of water, and is converted into carbonic acid and ammonia. A similar change is produced under the influence of certain micro-organisms, which are found in urine undergoing the alkaline fermentation. The best known of these is the micrococcus ureæ, from which a soluble hydrolytic enzyme may be extracted. The most prolific source of the urea enzyme is the mucous urine passed in inflammatory diseases of the bladder. In these cases the enzyme seems to be associated with mucin, and is presumably secreted by the mucous membrane. This explains why, in all inflammatory diseases of the bladder, the urine so readily undergoes the alkaline fermentation. When treated with nitrous acid, urea undergoes decomposition into CO_2, N, and H_2O. A similar decomposition is obtained by the action of NaClO or NaOBr.

$$(NH_2)_2CO + 3NaBrO = 3NaBr + CO_2 + N_2 + 2H_2O.$$

Since the volume of N evolved is constant for a given weight of urea, this reaction is made the base for the quantitative estimation of urea in urine. It may be detected in solution by evaporation with nitric acid or oxalic acid, and examining the crystals under a lens. Mercuric nitrate should give a precipitate in the absence of sodium chloride in excess. Yellow nitrous acid should produce an effervescence. With furfurol and hydrochloric acid, in not too dilute a solution, urea gives a play of colors passing rapidly from yellow through green, blue, violet, and finally purple. The estimation of urea will be considered in a chapter on the examination of urine.

The **origin of urea** in the body has been the subject of a great deal of discussion and experiment. There is no doubt that its origin is in the decomposition of muscular and other tissues. The immediate antecedents of urea are not so clearly known. It is supposed, however, that creatin, creatinin, glycin, leucin, and other members of the amido acid class are the intermediate products between the proteids on the one hand, and urea on the other. The seat of the changes of these amids into urea is supposed to be largely in the liver. In the case of leucin, the evidence of this is direct, and there is increasing evidence that this organ is largely concerned in the synthetic changes which lead to the formation of urea in mammals, and of uric acid in birds. Schroeder has shown that the conversion of $(NH_4)_2CO_3$ into urea occurs in the liver, and Minkowski has shown a similar relation to the formation of uric acid in birds. When the liver is diseased, leucin and tyrosin escape conversion, and appear in the urine, and at the same time there is a marked diminution in the excretion of urea. When urea is given to birds it appears externally as uric acid. These changes do not occur after extirpating the liver.

Uric Acid, $C_5H_4N_4O_3$,  $\begin{array}{l} NH-CO \\ \overset{|}{CO}\quad \overset{|}{C}-NH\diagdown \\ \quad\quad\quad\quad\quad\quad\quad\quad CO \\ \underset{|}{NH}-\underset{\|}{C}-NH\diagup \end{array}$, is a common constituent of urine in birds and reptiles, and occurs sparingly in this secretion in men and most mammals. It is present also in the spleen, and traces have been found in various other tissues. It sometimes occurs as a concretion or calculus in the bladder and kidneys. In gout, accumulations of uric acid salts deposit in certain tissues, especially about the joints. When pure, it is a colorless, crystalline, tasteless powder without odor. Its crystalline form is very variable, the shape of the crystals depending upon the condition of the fluid at the time of crystallization. To the naked eye, these crystals when separated from the urine, always appear reddish or yellow in color, but under the microscope they appear to be colored yellow throughout. Uric acid is remarkably insoluble in water, one part requiring 15,000 parts of cold water and 1,600 parts of boiling water to effect solution. It is insoluble in ether and alcohol. H_2SO_4 dissolves it in the cold without decomposition, as do also many of the alkaline salts and the caustic alkalies. Ammonia, however, does not dissolve it. It is fairly soluble in glycerin and to some extent in solutions of lithium carbonate. It occurs in the urine also in the form of the neutral and acid urates of sodium, the latter of which appears as a sediment, and is frequently spoken of as **lithates**, and the term **lithic acid** is sometimes employed instead of uric acid. In urine that has undergone alkaline fermentation, ammonium urate will frequently be found, occurring in the form of small, brown, nearly opaque balls with radiating spicules easily seen with a microscope of moderate power. The amount of uric acid in human urine is very small. Pathologically, it is found in considerable quantities. It may be prepared from human urine by adding from 2 to 3 per cent of strong HCl, and allowing the solution to stand for 24 hours in a cool place. The crystals form on the sides of the containing vessel and may be filtered out. It is usually prepared from guano or snake excrement. From the latter it is obtained by boiling with one part of KOH to 20 of water as long as NH_3 is evolved, when the solution is filtered. On cooling, CO is passed through the solution, when the acid urate of potassium precipitates. This salt is dissolved in KOH, and carefully neutralized with HCl, when the uric acid precipitates.

Detection of Uric Acid.—The acid is usually detected in the urine by the microscopic appearance of its crystals. It occurs in a variety of forms, all of which are more or less colored when separated from the urine, and appears as rhombic plates, or in whetstone-shaped crystals, occasionally in the form of dumb-bells, and often in groups embedded in one another. It may be detected also by evaporating the suspected solution nearly to dryness, cooling, adding a few drops of HNO_3, and evaporating to complete dryness on a water bath. The residue thus obtained is moistened with ammonia, when a brilliant, reddish-purple color is developed if uric acid be present. This color deepens on warming, while a similar color obtained by guano does not; thus the two substances are distinguished. The test depends on the formation of murexid, an ammonium salt of purpuric acid, and is known as the **Murexid test.** **Schiff's reaction** is obtained by dissolving the substance in Na_2CO_3, and bringing a drop of the solution in contact with a solution of $AgNO_3$ upon a piece of filter paper, when a yellow or black stain, due to the reduction of the nitrate of silver, is at once obtained. When heated with Fehling's fluid, uric acid reduces the copper with the production of a grayish precipitate of cuprous urate.

Uric acid is estimated quantitatively with some difficulty. The best method is that of Haycraft. According to this method the uric acid is precipitated by an ammoniacal solution of $AgNO_3$ in the presence of ammonium magnesium chloride. The precipitate contains one atom of silver to one molecule of uric acid. The precipitate is filtered out, dissolved in HNO_3, and the silver estimated volumetrically with a standard solution of potassium sulphocyanate, using a few drops of ferric alum as an indicator.

Uric acid contains the nucleus of two molecules of urea and is sometimes regarded as a diureid. In some of its decompositions, it yields urea as one of its products. For this reason it was formerly believed to be one of the antecedents of urea, and to be a stage in the oxidation of nitrogenous waste short of that necessary to produce urea. It occurs in increased amounts when, for any reason, the oxidation within the body is interfered with, as in diseases of the lungs, liver, or skin, or in excessive partaking of nitrogenous food. It may be diminished in such cases by agents that will increase the oxidation in the blood and tissues. By the oxidation of uric acid with nitric acid, it decomposes into a molecule of alloxan and one of urea. By further oxidation alloxan is converted into **parabanic acid** or oxal-urea and Co_2.

$$\underset{\text{Uric acid.}}{C_5H_4N_4O_3} + O + H_2O = \underset{\text{Alloxan.}}{C_4H_2N_2O_4} + \underset{\text{Urea.}}{(NH_2)_2CO}.$$

$$\underset{\text{Alloxan.}}{C_4H_2N_2O_4} + O = \underset{\substack{\text{Parabanic acid} \\ \text{or oxal-urea.}}}{C_3H_2N_2O_3} + CO_2.$$

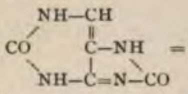
When parabanic acid is heated with alkalies, it forms oxaluric acid, and this by prolonged boiling is converted into urea and oxalic acid. By oxidation with $K_2Mn_2O_8$, uric acid is decomposed into allantoin and CO_2. Allantoin with HNO_3 gives urea as one of its decomposition products.

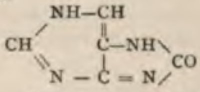
Oxaluric Acid, $C_3H_4N_2O_4$, occurs in minute traces in human urine, and is a white crystalline powder, not very soluble in water. Its alkaline salts, however, are readily soluble.

Allantoin, $C_4H_6N_4O_3$, is a characteristic constituent of the allantonic fluid and of the amniotic fluid. It is also found in the urine of many animals for a short period after their birth. It is found in the urine after the internal administration of uric acid. It has been found also in vegetable tissues. It crystallizes in small, shining, colorless, hexagonal prisms, soluble in 160 parts of cold water, and insoluble in cold alcohol and ether. The alkalies dissolve it, forming salts. It gives no reactions which are sufficiently characteristic to admit of its detection in urine or other fluids. It must be separated from them and be obtained in the crystalline form. Allantoin has been obtained synthetically by heating together glyoxalic acid and urea.

Alloxan, $C_4H_2N_2O_4$.—This is another of the decomposition products of uric acid under mild oxidation. It has been found in the intestinal mucus in cases of diarrhœa. It crystallizes in colorless crystals, readily soluble in water.

Murexid — Ammonium Purpurate—$C_8H_4(NH_4)N_5O_6$, is produced by the oxidation of uric acid, alloxan, guanin, and a number of other derivatives of uric acid, with a subsequent treatment with NH_4OH. It is an ammonium salt of a hypothetical acid which has not yet been isolated. It is of a brilliant reddish-purple color, and has before been referred to in the **murexid test** for uric acid.

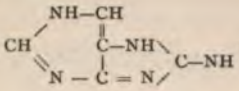
Xanthin,  $= C_5H_4N_4O_2$, was first discovered in urinary calculi and called xanthic oxide. It is a normal, though scanty, constituent of urine, muscle, liver, spleen, thymus, and brain substance. It occurs in large quantities together with hypoxanthin in "extract of meat," and is also found in traces in certain vegetable tissues. In nearly all cases it is accompanied by hypoxanthin. It may be prepared from extract of beef. When pure, it is a colorless powder, almost insoluble in water, alcohol, and ether, but it dissolves readily in diluted acids and alkalies, forming crystallizable compounds.

Hypoxanthin — Sarcin —  $= C_5H_4N_4O$, is closely related to xanthin and usually occurs with it in the tissues and fluids of the body. It is obtained from fluids or tissue extracts. A silver salt of xanthin and hypoxanthin is employed for their separation from fluids.

Methylxanthin — Heteroxanthin — $C_6H_6N_4O_2$, occurs in minute quantities in the normal urine of man and dog along with xanthin, hypoxanthin, and paraxanthin.

Dimethylxanthin — Paraxanthin—$C_7H_8N_4O_2$, is an isomer of theobromine. As stated above, it occurs in very small amounts in urine, and is closely related to the above compounds. Its physiological action, when administered internally, is identical with that of theobromine.

Carnin, $C_7H_8N_4O_3$, is another base closely allied in composition to the above compounds. It occurs in extract of meat, of which it forms about one per cent. It may be prepared by precipitating extract of meat with BaO_2H_2 water, avoiding excess. The precipitate is filtered out, and the carnin precipitated from the filtrate with basic lead acetate. The precipitated lead salt is suspended in hot water, and the lead separated with H_2S; the filtrate is concentrated and the carnin crystallized out. It separates in white masses composed of very irregular crystals, readily soluble in hot water, slightly soluble in cold water, and insoluble in alcohol and ether. It unites with acids and salts to form crystalline compounds. Carnin may be converted into hypoxanthin by treatment with chlorine or HNO_3, or still more readily by bromine.

Adenin,  $= C_5H_5N_5$, is another base closely related to xanthin in composition, and was first obtained from the pancreatic tissue. It is said to have been found in the urine. A number of the foregoing compounds, as will be seen, occur in the extract of meat. It has been proved that the chief virtue of extract of meat is in the stimulant properties of these bases.

Guanin, $C_5H_5N_5O$, is found in Peruvian guano and in small quantities in the pancreas, liver, muscle extract, and many of the products of the action of acids upon nuclein. It may also occur in the urine. It is a white, amorphous powder, insoluble in water, alcohol, ether, and ammonia.

Guanidin, CN_3H_5, is one of the oxidation products of guanin. It does not occur in the free state in any of the normal tissues or fluids of the body, but has been obtained by the oxidation of proteids. It may be made to yield urea by treatment with hot dilute H_2SO_4. It has also been obtained by synthesis.

Indol, C_8H_7N, occurs characteristically in the fæces, to which, with skatol, it imparts their unpleasant odor. It is formed during the putrefactive decomposition of proteids, which usually occur, to a greater or less extent, in the alimentary canal. A part of the indol leaves the body by the urine as a potassium salt, or as **indoxyl sulphuric acid.** The remnant passes out with the fæces. It may be obtained, together with phenol and skatol, by acidulating and distilling the products of a somewhat prolonged, alkaline, putrefactive, pancreatic digestion of proteids. Indol passes over with the distillate, from which it is extracted by shaking with ether, as an oily liquid when the ether evaporates. It may also be prepared by heating most proteids with excess of KOH. Indol is a crystalline body soluble in boiling water, alcohol, and ether. It may be detected as follows:—A strip of pine wood, moistened with HCl, is colored a bright crimson when dipped into an alcoholic solution of indol. The alcoholic solution turns red when treated with nitrous acid. Its aqueous solution gives a red precipitate with the same reagent.

Skatol—Methylindol—C_9H_9N, occurs also in human fæces together with indol, being present in larger amounts than the latter. The conditions of its production are the same as those for indol, so that the two substances occur mixed in the products of putrefactive decomposition of proteids, and of the action of caustic potash upon proteids at a high temperature. A portion of the skatol produced in the intestine is absorbed, oxidized, and appears in the urine as **skatoxyl sulphuric acid.**

Indoxyl-sulphuric Acid, $C_8H_6NOSO_2OH$, is the indican frequently mentioned as occurring in the urine. This compound is not identical with the indican found in plants, which is a glucoside. It is in reality a sulphuric ether of indoxyl, C_8H_6NOH, a compound similar to phenol and cresol. Indican is increased in carnivorous animals, under a meat diet, but is not increased by the administration of gelatin. It is more plentiful in the urine of herbivora than of carnivora. Indoxyl sulphuric acid occurs in the urine combined mostly with potassium. When warmed with HCl it decomposes into indoxyl and acid potassium sulphate.

$$\underset{\text{Potassium indoxyl sulphate.}}{C_8H_6NOSO_2OK} + H_2O = \underset{\text{Indoxyl.}}{C_8H_6NOH} + KHSO_4.$$

Indoxyl by oxidation is converted into indigo blue.

$$2C_8H_6NOH + O_2 = C_{16}H_{10}N_2O_2 + 2H_2O.$$

The formation of indigo blue is used in Jaffé's test for indican in the urine. The test is applied as follows:—10 c. c. is mixed with an equal volume of strong HCl and 2 to 3 c. c. of chloroform. A strong solution of chloride of lime is then added, drop by drop, shaking after the addition of each drop. If indican be present, the chloroform, on separating and standing, will be colored more or less deeply blue, according to the amount of indican present. Skatol also occurs in the urine. When Jaffé's test for indican is applied to urine which contains skatoxyl compounds, the urine turns red or violet on the addition of HCl, and bright crimson on the addition of HNO_3. A similar color is obtained if it is warmed with HCl and Fe_2Cl_6.

Indigo Blue, $C_{16}H_{10}N_2O_2$, is formed as above stated from indican, and gives rise to the blue color sometimes observed in sweat and urine. It may be obtained by slow formation from indican, in fine crystals insoluble in water, but slightly soluble in alcohol, ether, chloroform and benzene. Indican is soluble in strong H_2SO_4, forming two sulphonic acids. The sodium salts of these acids are soluble in water, and when mixed with sodium sulphate, constitute "indigo carmine" of commerce; and in the pure form of sulphindigotate of soda, is employed as a test for sugar in the urine. Indigo possesses a pure blue color, and leaves a red streak when drawn across a hard body. Treated with reducing agents in strongly alkaline solution it is reduced to indigo white; on exposure to air the indigo white again becomes indigo blue. It thus proves a convenient reaction for the detection of indigo, or for reducing substances like dextrose.

Biliary Acids.—The bile contains the sodium salts of two amido-acids and several acids derived from these by decomposition. The two acids contained in the bile are glycocholic and taurocholic acids.

Glycocholic Acid, $C_{26}H_{43}NO_6$, occurs in bile as a sodium salt. The acid occurs in two forms, the one as fine crystalline needles, and the other as an amorphous resinous solid. It is monobasic. It is soluble in hydrochloric, sulphuric, and acetic acids, without decomposition; soluble in glycerin, slightly soluble in cold, and readily in hot water; very soluble in alcohol, and insoluble in ether. When boiled with alkalies or mineral acids it splits up into **cholic acid** and **glycocin.**

$$C_{26}H_{43}NO_6 + H_2O = \underset{\text{Cholic acid.}}{C_{24}H_{40}O_5} + \underset{\text{Glycocin.}}{C_2H_3NH_2O_2}.$$

Taurocholic Acid, $C_{26}H_{45}NSO_7$, occurs in small quantity in human bile, but in larger quantity in that of the carnivora. It is soluble in water and alcohol. With boiling alkaline or acid solutions, it forms **cholic acid** and **taurin,** $C_2H_7NSO_3$. The spontaneous decomposition of bile causes the same change.

Both glycocholic and taurocholic acids form salts which have the power of dissolving cholesterin and of emulsifying fats. They also form insoluble compounds with the salts of the alkaloids and with peptone. These salts are soluble, however, in excess of the biliary salts. The taurocholate of morphine is crystallizable. The glycocholate of sodium exists in the bile, and may be prepared from fresh ox bile. They may be precipitated from neutral solutions by lead acetate, but the precipitate is soluble in an excess of the precipitant.

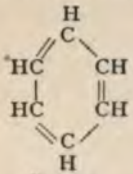
Tests for Biliary Acids.—To a solution of the biliary acids add a few drops of a solution of cane sugar (1 to 10), and then strong sulphuric acid. A cherry red, followed by a deep purple violet color is produced. This test, known as Pettenkofer's, cannot be applied to organic mixtures, as urine, because numerous other bodies give the same color.

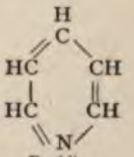
To apply it to such mixtures, evaporate to dryness, exhaust the residue with absolute alcohol, decolorize the solution with animal charcoal, evaporate to dryness, dissolve in water, and then test as above.

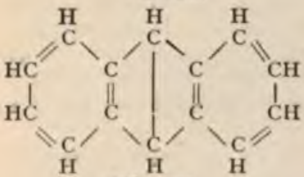
ARTIFICIAL ORGANIC BASES.

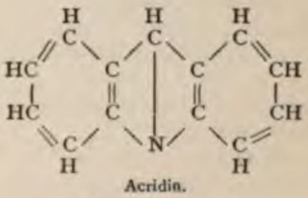
The most of these bases may be regarded as aromatic hydrocarbons, in which one nitrogen atom has taken the place of the triad group CH'''.

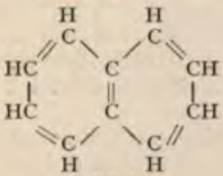
The following graphic formulæ will show the relation of these bases to the corresponding hydrocarbons:

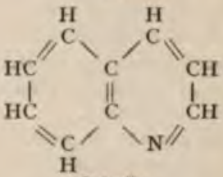

Benzene.


Pyridin.


Anthracene.


Acridin.


Naphthalene.


Quinolin.

The Pyridin Bases.—These artificial bases are produced by the decomposition of bone gelatin, or ossein, in the destructive distillation of bones. They form a series of homologous bases which have received the name of pyridin bases. Some of them have also been found in coal tar. They are liquids of a disagreeable, pungent, tarry odor, and belong to the tertiary monamins. They may be extracted from the offensive oil known as Dippel's oil, obtained from the distillation of bones. By the addition of, or by shaking the oil with H_2SO_4, sulphates of the bases are produced which dissolve in water. The bases may be separated again on adding potash or soda. They are separated from each other by fractional distillation. The pyridin bases are often present in commercial ammonia. Their names are as follows:—

	Boiling points.		Boiling points.
Pyridin, C_5H_5N,	115° C. (239° F.)	Parvolin, $C_9H_{13}N$,	188° C. (370.4° F.)
Picolin, C_6H_7N,	133° C. (271° F.)	Coridin, $C_{10}H_{15}N$,	211° C. (411.8° F.)
Leutidin, C_7H_9N,	154° C. (309° F.)	Rubidin, $C_{11}H_{17}N$,	230° C. (446° F.)
Collidin, $C_8H_{11}N$,	170° C. (338° F.)	Viridin, $C_{12}H_{19}N$,	251° C. (483.8° F.)

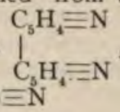
Pyridin is obtained from Dippel's oil, and is also obtained synthetically from piperidin, which is itself derived from black and white pepper. It may be prepared synthetically by a number of other reactions. It is a colorless liquid with a tarry odor and pungent taste. It boils at 115° C. (239° F.), and has a sp. gr. of .9858. It is miscible with water in all proportions, and is hygroscopic. It forms salts with acids by direct addition, like the alkaloids; and, indeed, many of the alkaloids are believed to be salts of this base. It has been employed in medicine in 3- to 4-drop doses as a stimulant in heart disease. It has been used as a local application in diphtheria, and, by evaporation into the air, in the treatment of asthma. For medicinal uses it should not be altered by exposure to light. Pyridin bases occur in tobacco smoke.

Pyrrol, C_4H_5N, is a weak liquid base occurring in coal-tar and in Dippel's oil, from which it may be extracted by sulphuric acid and distilling from the sulphate with a stronger base. It possesses an odor similar to that of chloroform. By the action of the ethereal salts of iodine upon pyrrol, a **tetra-iodo-pyrrol** is obtained, C_4I_4NH. This compound is used in medicine under the name of **Iodol.**

Iodol occurs as a grayish-brown, odorless, tasteless powder. It is of a light yellow color when pure, and is more or less crystalline. It decomposes between 140° and 150° C. (284° and 302° F.) and evolves iodine vapors. It is soluble in alcohol and ether, but is sparingly so in water.

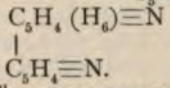
Derivatives of Pyridin.—Three isomeric methyl pyridins are known under the name of **picolins**, and are found in coal-tar. β methyl-pyridin may by prepared by distilling strychnine with lime. It is a liquid of unpleasant pungent odor. Di-methyl pyridin, $C_5H_3\ (CH_3)_2N$, Tri-methyl pyridin, $C_5H_2\ (CH_3)_3N$, Ethyl-pyridin, $C_5H_4\,(C_2H_5)N$, and Propyl-pyridin, $C_5H_4\,(C_3H_7)N$ are also known. Pyridin like benzine is capable of taking up six more hydrogen atoms, forming hexahydro-pyridin or **piperidin,** $C_5H_5NH_6$, a colorless liquid having a peculiar peppery odor. It is a strong base and forms a series of crystalline salts. Piperidin may be obtained, along with piperic acid, by treating piperine from pepper with an alcoholic solution of KOH.

Conine, $C_6H_4\ (C_3H_7)\ NH_6$, is propyl-piperidin. **Nicotine** is a hexahydro-dipyridyl, or formed from two molecules of pyridin. Dipyridyl has the formula



$$\begin{array}{l} C_5H_4{\equiv}N \\ | \\ C_5H_4{\equiv}N \end{array},$$

and nicotine the formula

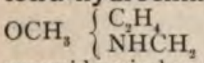


$$\begin{array}{l} C_5H_4\ (H_6){\equiv}N \\ | \\ C_5H_4{\equiv}N. \end{array}$$

Quinolin Bases.—These are compounds which are generally derived from coal tar, and are closely related to naphthaline. Bases similar to, and isomeric with a few of these, have been obtained by the distillation of some of the alkaloids with potash. **Quinolin or Chinolin,** C_9H_7N, has been prepared both from the alkaloids and from coal tar. It has been prepared by the action of H_2SO_4 and nitrobenzene upon anilin and glycerin. The mixture is heated to 130° C. (266° F.), the lamp removed when reaction begins, and then heated again for three hours, and finally distilled with lime, when quinolin distils over with anilin, from which it may be separated by fractional distillation. It may also be obtained by distilling quinine with an alkali. When pure, quinolin or chinolin, is a colorless liquid, with a characteristic, aromatic, pungent odor, of sp. gr. 1.084. It is freely soluble in alcohol, ether, chloroform, and hot water. It is insoluble, or only slightly soluble, in cold water. It has been employed as an antiseptic and antizymotic, and as an antipyretic. For internal use a tartrate, salicylate, tannate, bisulphate, and hydrochlorate have been recommended. When quinolin is treated with H_2SO_4 it yields a sulphonic acid. When this is treated with nascent hydrogen, and the resulting product with methyl iodide, the body of $C_9H_{10}O(OCH_3)$ or $C_{10}H_{13}\,NO$, **methyloxyquinolin,** is produced. This substance closely resembles quinine, $C_{20}H_{24}$

N_2O_2. Its hydrochlorate of oxyquinolin is used medicinally under the name of **kairin**, $C_9H_7NO.HCl$, as a substitute for quinine. The corresponding ethyl derivative $C_9H_7(C_2H_5)NO.HCl$ is also employed for the same purpose. The kairins act as powerful antipyretics, but their use has been attended with unpleasant after effects. Quinolin forms substitution products and hydrogen addition products. The hydroxyl derivatives are called oxyquinolins.

A number of derivatives of the oxy-quinolins have found use in medicine.

Thalin is an antipyretic remedy, metameric with kairin, **tetra-hydrochin-anisol.** Its constitution is as follows: C_6H_3  $OCH_3\left\{\begin{matrix}C_2H_4\\NHCH_2\end{matrix}\right.$ or $C_6H_{10}NOCH_3$. It is prepared by heating paramidoanisol and paranitroanisol with glycerin and H_2SO_4, and reducing the product with nascent H. It is a strong base, crystallizing in colorless prisms, having a bitter, saline, pungent taste. It melts at 42°C. (107.6° F.), and is insoluble in water, but is readily so in alcohol, ether, chloroform, and benzene. Thallin forms a series of well-defined salts. A sulphate and a tartrate have been used in medicine. The former is a yellowish-white, crystalline powder, of a saline, bitter, and spicy taste. It is soluble in 7 parts of cold water. It is also soluble in alcohol, but almost insoluble in chloroform and ether. With iodine, its solutions give a brown precipitate; with tannic acid white; with Nessler's reagent lemon-yellow; with Fe_2Cl_6 an emerald green. The tartrate closely resembles the sulphate in most of its properties. These compounds are blood poisons, *i. e.*, they disintegrate the red-blood corpuscles.

NATURAL ORGANIC BASES, OR ALKALOIDS.

Many plants, and especially those having medicinal and poisonous properties, contain basic principles or compounds containing nitrogen, which are called **alkaloids.** Some are volatile while others decompose when heated. Most of them resemble the amins or **compound ammonias** in properties, while some correspond more nearly to the ammonium compounds. Most alkaloids are sparingly soluble in water, and more freely in alcohol, the solutions having an alkaline reaction and bitter taste. They combine directly with acids, like NH_3, forming crystalline salts, which are generally soluble in water. Their hydrochlorates form crystalline double salts with the chlorides of gold, platinum, mercury, etc. Most of them are precipitated solutions of tannin, the double iodide of potassium and mercury, double iodide of cadmium and bismuth, phosphomolybdic, phosphoantimonic, phosphotungstic, and picric acids, and by a solution of iodine in potassium iodide or hydriodic acid. These reagents are, therefore, used to precipitate the alkaloids from other substances found with them. By treating these precipitates with an alkaline hydroxide, the bases are separated.

PROPERTIES OF THE NATURAL ALKALOIDS.

The true vegetable alkaloids, or plant bases are very numerous. Many of them are imperfectly known, while others have been studied very completely. The alkaloids are generally found in all parts of plants, though in some cases they are restricted to certain portions. The vegetable alkaloids are in most cases intensely poisonous, while in others, as the alkaloids of coffee, cocoa, and cinchona, they produce characteristic physiological effects, but are not actively poisonous. They generally have a bitter taste. Most of them are solid at ordinary temperatures. The non-oxygenized, volatile bases are liquid. The alkaloids are alkaline in reaction. They unite with acids to perfect neutrality and form well-defined crystallizable salts. In some cases the basic character is feebly marked, when no acids exist, and even the salts with the stronger acids are easily decomposed. As a rule, the vegetable alkaloids, except the volatile bases, are sparingly soluble in water, and are, therefore, usually precipitated by the addition of a solution of a strong base to a solution of their salts. They are nearly all readily dissolved by alcohol except rhœadine and pseudomorphine.

The salts of the alkaloids are generally more soluble in water than the bases themselves, and, as a rule, dissolve on the addition of alcohol. As a rule, the alkaloids form a class of double salts, *i. e.*, chloroplatinates, mercuro-iodides, etc., with platinic chloride and mercuric iodide. Immiscible solvents, such as chloroform, amyl, alcohol, ether, benzene, and bisulphide of carbon, differ considerably in their solvent powers of alkaloids and alkaloidal salts.

Nomenclature of Alkaloids.—While there is a great deal in favor of the reform in spelling of many chemical terms, and while we have adopted the practice of dropping the final *e* in the artificial bases and compound ammonias, we shall retain the final *e* in the spelling of the names of the alkaloids. The alkaloids, being very active and frequently poisonous substances, should be sharply distinguished from the glucosides and bitter principles, and the very numerous synthetical substances recently introduced into medicine. This distinction, which has existed for years, and which is well fixed in the minds of a large proportion of the physicians and pharmacists of all English-speaking countries, will be preserved by retaining the final *e*. Thus, we shall use *morphine* instead of *morphin*, and *quinine* instead of *quinin*.

Reagents for Precipitating Alkaloids.—Alkaloids as a class give precipitates with a considerable number of reagents, especially the compounds of the heavy metals. Of these precipitants the most generally used are a solution of I in KI solution, a solution of phosphomolybdic acid (Sonnenschein's reagent), and a solution of the double iodide of mercury and potassium (Mayer's reagent). With the exception of tannin, which should be employed in neutral or slightly alkaline solution, the precipitants of alkaloids are usually added to the solution slightly acidulated with H_2SO_4 or acetic acid.

Mayer's Reagent is made by dissolving 13.546 grms. of mercuric chloride and 49.8 grms. potassium iodide in 1000 c. c. of water. This solution precipitates all alkaloids, forming white or yellowish-white crystalline compounds of definite composition, for which reason this solution is used for the volumetric estimation of alkaloids.

Phosphomolybdic Acid, mentioned above as a reagent for alkaloids, is prepared as follows:—Dissolve 15 grms. ammonium molybdate in a little ammonia water and add water to make 100 c. c. This solution is poured into 100 c. c. of strong nitric acid, and this mixture is added to a warm 5 per cent. solution of sodium phosphate, as long as a precipitate forms. The precipitate is collected on a filter, washed, dissolved in a very little NaOH solution, and evaporated to dryness, or heated, until all NH_3 escapes. The residue is to be dissolved in about 10 parts of water, and enough HNO_3 added to redissolve the precipitate which at first forms. This reagent gives precipitates not only with alkaloids, but also with salts of ammonium and potassium.

Both of these reagents, while being delicate tests for alkaloids, precipitate albuminous and other matter not alkaloidal in nature.

Picric Acid is employed as a saturated aqueous solution. It is very suitable for precipitating the cinchona bases, emetine, berberine, and veratrine.

Iodine dissolved in a solution of potassium iodide (**Wagner's reagent**) yields reddish or red-brown precipitates with nearly all alkaloids, even in very dilute solutions. The precipitates form more readily in solutions rendered slightly acid with H_2SO_4. Excess of the reagent should be avoided. This test is so generally successful in precipitating alkaloids, that a negative reaction is conclusive proof of the absence of ordinary alkaloids, although precipitation is not absolute proof of the presence of an alkaloid. In alcoholic solutions, the precipitates are deposited slowly, sometimes not at all, owing to their solubility in alcohol. The strength may vary within wide limits. A solution containing 20 grms. of iodine and 50 grms. of potassium iodide per liter is about the right strength.

Marme's reagent is a solution of the double iodide of potassium and cadmium. It is employed in solutions acidulated with H_2SO_4, and gives characteristic precipitates with many of the alkaloids.

The double iodide of potassium and bismuth (Dragendorff's reagent) is made by saturating a hot concentrated solution of potassium iodide with bismuth iodide, and then adding an equal volume of a cold, saturated solution of potassium iodide. It cannot be diluted, but is applicable to solutions of alkaloids strongly acidulated with H_2SO_4.

Platinic chloride and auric chloride are frequently employed to precipitate alkaloids and to distinguish them from other bitter principles. Platinic precipitates have a yellow or yellowish-red color. The gold precipitates of a number of the alkaloids blacken, by reduction, on standing.

Color Reactions.—Many of the alkaloids give characteristic colors, when in the pure state, by treatment with certain reagents. These color reactions are subject to variations by impurities, concentration, temperature, and by time. Color reactions are, therefore, confirmatory rather than conclusive, and should always be confirmed by control tests upon a portion known to be the alkaloid in question. The reagents that are employed to give color tests are:—(1) **Concentrated sulphuric acid**; (2) **Fröhde's reagent,** concentrated sulphuric acid, containing molybdic acid (1 mgm. molybdic acid to 1 c.c. H_2SO_4); (3) **Nitric acid,** sp. gr. 1.40 to 1.42; (4) **Sulphuric acid, followed by a minute addition of HNO_3 or KNO_3;** (5) **Sulphuric acid,** and **cane sugar.** The dry substance to be tested is mixed with six parts of cane sugar, and a few mgms. of the mixture are placed upon a drop or two of pure H_2SO_4 on a white plate.

The colors given by a number of the most important alkaloids with some of these reagents are given in a table on page 473.

Separation of Alkaloids.—The vegetable substance, the seed, bark or leaf, is first disintegrated and extracted thoroughly with slightly acidulated water, which dissolves out the alkaloid. The volatile alkaloids are recovered from the solution by distillation after the addition of an alkali. Non-volatile alkaloids may be precipitated from an acid solution by an alkali, and the impure base thus obtained may be filtered out and dissolved in acids, and purified by recrystallization. Or, the precipitated alkaloids may be dissolved in alcohol, in which they are generally soluble, and the alcohol evaporated off. In some cases alcohol is employed for the extraction of alkaloids, as most of the alkaloids and alkaloidal salts are soluble in alcohol.

The separation and detection of alkaloids in organic mixtures, especially when present in small quantities, requires an expenditure of considerable time and patience. When it is undertaken in toxicological examinations, it should only be by an expert who

COLOR REACTIONS OF ALKALOIDS.

"O" indicates "*colorless*."

ALKALOID.	PURE H_2SO_4.	H_2SO_4 $+HNO_3$.	H_2SO_4 +SUGAR.	FRÖHDE'S R.	HNO_3.	CONC. HCl.	H_2SO_4 $+K_2Cr_2O_7$	Fe_2Cl_6.	OTHER REACTIONS.
Aconitine.	Grad. violet.	Grad. violet.	Fine red.	Yellow-brown.	Reddish-brown.	O		In aq. sol. yellow ppt.	The phosphomolybdic acid precipitate rapidly turns blue.
Atropine.	O	O	O	O	O	O	Dis-colored.	Not pptd.	Dilates the pupil.
Berberine.	Olive-green.	Olive-green.		Brown-green.	Brown-red.				The addition of a few drops of chlorine water to a solution of berberine in not too small a quantity of hydrochloric acid, produces a red color.
Brucine.	O	Red.	O	Red	Red.	O	Orange.		Boiled with perchloric acid a madeira color is developed. A solution in dilute sulphuric acid (1.8) is turned fine red by bichromate of potassium.
Caffeine.	O	O	O	O	O	O	O	Not pptd.	The residue obtained by dissolving in chlorine water and evaporating is colored red by ammonia.
Quinine.	O	O	O	Greenish.	O	O	Light Yellow.	Not pptd.	The chlorine-water sol. is colored green by ammonia, red-brown with ammonia and ferricyanide of potassium.
Cinchonine.	O	O	O	O	O	O			Remains colorless when treated as above.
Cinchonidine.	O	O	O		O	O		Not pptd.	do. do.
Colchicine.	Yellow.	Blue.	Yellow.	Yellow.	Blue.	O	Green then brown.		If the blue color produced by adding saltpetre to the solution in H_2SO_4 is allowed to fade away, the residue is colored red by potash.
Quinidine.	O	O	O	Greenish.	O	O			Like quinine.

COLOR REACTIONS OF ALKALOIDS.—*Continued.*

"O" indicates "*colorless.*"

ALKALOID.	PURE H_2SO_4.	H_2SO_4 $+HNO_3$.	H_2SO_4 +SUGAR.	FRÖHDE'S R.	HNO_3.	CONC. HCl.	H_2SO_4 $+K_2Cr_2O_7$	Fe_2Cl_6.	OTHER REACTIONS.
Coniïne.	O	O	O	O	O	O			The hydrochloric acid solution leaves a crystalline residue when evaporated.
Gelsemine.	Yellow-red.		Red.						Sulphuric acid and oxide of cerium color it cherry-red.
Hyoscyamine.	O	O	O	O	O	O	Discolored.	Not pptd.	Dilates the pupils.
Codeine.	O	Grad. blue.	Red.	Grad. deep blue.	Yellow.		Olive-green.	O	Warmed with sulphuric acid and a little ferric chloride, turns blue.
Morphine.	O	Violet.	Red.	Violet.	Yellow.	O	Brown.	Blue.	Reduces iodates, nitrate of silver, ferricyanide of potassium, etc.
Narcotine.	Grad. raspberry.	Reddish-violet.				O			Fine red color is developed when the solution in dilute sulphuric acid is evaporated.
Nicotine.	O	O	O	O	O	O			The hydrochloric acid solution leaves an amorphous residue when evaporated.
Papaverine.	O	O			Orange.	O			Turns blue, warmed with sulphuric acid.
Physostigmine.	Grad. red.	Grad. red.			Red.	Reddish.			Solution of chloride of lime colors red. The precipitate with potassio-mercuric iodide is soluble in alcohol. Physostigmine produces tetanus.
Pilocarpine.	O	O					Green.		
Piperine.	Grad. green.	Grad. green.		Yellow then brown.	Orange.			Ppt. in HCl Sol.	

COLOR REACTIONS OF ALKALOIDS.—*Continued.*

"O" indicates "*colorless.*"

ALKALOID.	PURE H_2SO_4.	H_2SO_4 $+HNO_3$.	H_2SO_4 +SUGAR.	FRÖHDE'S R.	HNO_3.	CONC. HCl.	H_2SO_4 $+K_2Cr_2O_7$	Fe_2Cl_6.	OTHER REACTIONS.
Solanine.	Light reddish.	Light reddish.			Margin blue.				A hot mixture of equal volumes of alcohol and sulphuric acid is colored by solanine.
Strychnine.	O	O	O	O	O	O	Blue, passing quickly to violet and red.	Brownish-green ppt.	The blue coloration produced by H_2SO_4 and oxide of cerium is finer than with bichromate.
Theobromine.	O	O	O	O	O	O	O	Not pptd	Like caffeine.
Thebaine.	Blood-red.	Red		Orange.	Yellow.	Yellow.			
Veratrine.	Grad. fine cherry-red.	Grad. fine cherry-red.	Grad. blue.	Grad. cherry-red.	Yellow.	Red.	Reddish-brown.	Ppt. in HCl sol.	

has made himself thoroughly familiar with the minutest details of the work. It should not be undertaken by any one without a sufficient feeling of responsibility. The general method employed in such cases is, in outline, as follows:

First. The substance to be examined is properly divided, or disintegrated, and digested at about from 40° to 50° C. (104° to 122° F.), with water slightly acidulated with H_2SO_4. After this digestion the solution is filtered and the filtrate evaporated over a water-bath to a thin syrup. This is then mixed with alcohol and digested for several hours at about 30° to 40° C. (86° to 104° F.), cooled, filtered, and again evaporated nearly to dryness. The alkaloids will be found in this residue as sulphates. A small quantity of water is now added, and the solution submitted to a series of immiscible solvents—first to the acidulated solution, and then to the same solution made alkaline. The acidulated solution is transferred from the evaporating vessel to a separating funnel, thoroughly and repeatedly shaken for a few minutes with freshly rectified petroleum ether, which should boil at about 65° to 70° C. (149° to 158° F.). The treatment is repeated until on evaporating a small portion of the ether it leaves no residue, showing that it ceases to dissolve anything. Petroleum ether removes mostly the coloring matter, etc., but none of the alkaloids.

Second. This same process is to be repeated with benzene, the boiling point of which is 81° C. (177.8° F.). This removes digitaline, cantharidine, and santonine, which are crystalline, and elaterine, and colchicine, which are amorphous.

Third. A solution which has been treated as above is next shaken with chloroform, which removes cinchonine, digitaline, and pyrotoxine. The chloroform is next dissolved out of the solution by again shaking with petroleum ether.

Fourth. The solution is now made alkaline with ammonium hydroxide, NH_4OH, and shaken with petroleum ether at a temperature of about 40° C. (104° F.), when in the petroleum ether will be found any strychnine, quinine, brucine, and veratrine, if they are present. In a similar manner, petroleum dissolves coniïne and nicotine.

Fifth. The solution is next shaken with benzene, C_6H_6, when any remaining strychnine, brucine, quinine, cinchonine, atropine, hyoscyamine, physostigmine, aconitine, codeine, and narceine will be dissolved out.

Sixth. Chloroform is next employed in a similar manner, which removes traces of morphine if this alkaloid be present.

Seventh. Amyl alcohol is then employed in a similar manner, which dissolves morphine, solanine, and the glucoside salicin, if present.

Eighth. Evaporate the watery liquid with powdered glass and treat the residue with chloroform, when curarine, if present, will be extracted. After all these immiscible solvents have been separated, it then becomes necessary to isolate the residue by distillation of the solvent and, by proper tests, determine the alkaloid present.

The most important alkaloids with their behavior with immiscible solvents are given in tabular form on pages 477 and 478, with their formulæ and solubilities. Of the volatile alkaloids two only are of importance.

VOLATILE ALKALOIDS.

Coniïne, $C_8H_{17}N$, an alkaloid obtained from *Conium maculatum*, is a colorless, oily liquid having an acrid taste and a disagreeable odor. It can be distilled when protected from the air. It boils at 170° C. (338° F.). It is sparingly soluble in water, but is more soluble in cold than in hot water, is soluble in all proportions in alcohol. It is soluble in six volumes of ether, and is soluble in most fixed and volatile oils. On exposure to the air, it becomes thick and resinous. It gives off vapors, at the ordinary temperature of the air, which form white fumes with HCl, similar to ammonia. It has been obtained synthetically from butyric aldehyde and alcoholic solution of ammonia. When heated with H_2SO_4, it gives a red color changing to green, and an odor of butyric acid. With nitro-benzene it gives a blue color changing to red and yellow.

Lobeline is a volatile liquid alkaloid found in *lobeliæ inflata*. It has an odor and taste resembling that of tobacco.

Nicotine, $C_{10}H_{14}N_2$, occurs in tobacco. It is a colorless, oily liquid which turns brown on exposure to light and air. It has a bitter, caustic taste, and disagreeable penetrating odor. It distils at 250° C. (482° F.), and burns with a luminous flame. It is soluble in water, alcohol, ether, and the oils. It may be removed from its aqueous solution by shaking with ether. Its salts are deliquescent and crystallize with difficulty. It gives a violet color with HCl, and an orange with HNO_3. It is actively poisonous, producing death, when given in sufficient doses, sometimes with great rapidity.

Piperidine, Hexa-hydro-pyridin, $C_5H_5N.H_6$, has been found in pepper, where it occurs as a decomposition product of piperine. It has been prepared synthetically. (See page 466).

Piturine, $C_{12}H_{16}N_2$, occurs in the dried leaves of *Duboisia hopwoodii*, a plant growing in Australia and used by the natives to prepare a narcotic stimulant known as **Pituri.**

Sparteine, $C_{15}H_{26}N_2$, is an alkaloid extracted from the common broom, *scoparius*.

It is a liquid, heavier than water, boiling at 288° C. (550° F.). It is sparingly soluble in water, giving an alkaline, bitter solution. It smells like anilin, and, like it, becomes brown on exposure to the air. The sulphate is used in medicine as a heart stimulant.

NATURAL ALKALOIDS.

NAME.	FORMULA.	SOLUBLE IN WATER.	AMMONIA WATER.	BENZENE.	ETHER.	CHLOROFORM.	SOURCE.
Aconitine, ...	$C_{33}H_{45}NO_{12}$	S. in 150 pts.	S.S.	S.	S. in 2 pts.	S. in 2½ pts.	Aconitum napellus.
Atropine, ...	$C_{17}H_{23}NO_3$	S. in 60 pts.	S.	S. in 50 pts.	S. in 30 pts.	S. in 4 pts.	Atropa belladonna.
Apomorphine, . .	$C_{17}H_{17}NO_2$	Ins.	. .	S.	S.S.	S.S.	Morphine.
Berberine, ...	$C_{20}H_{17}NO_4$	S.S.	S.S.	. .	Insol.	S.S.	Berberis vulgaris. Calumba root.
Brucine, ...	$C_{23}H_{26}N_2O_4.4H_2O$	In 500 pts. boiling.	S.	S. in 60 pts.	Insol.	S. in 4 pts.	Nux vomica.
Caffeine, ...	$C_8H_{10}N_4O_2$	In 90 pts.	S.	S.	S. in 500 pts.	S in 5 pts.	Coffee and tea.
Cinchonine, . . .	$C_{19}H_{22}N_2O$	In 2500 pts. boiling.	Insol.	S.	S. in 400 pts.	S. in 60 pts.	Cinchona bark.
Cinchonidine, . .	$C_{19}H_{22}N_2O$	In 2000 pts.	. .	. .	S. in 150 pts.	. .	Cinchona bark.
Cocaine, ...	$C_{17}H_{21}NO_4$	In 704 pts.	. .	. .	S.	. .	Erythoxylon coca.
Codeine, ...	$C_{18}H_{21}NO_3$	In 75 pts.	In 75 pts.	S. in 12 pts.	S.	S.	Opium.
Colchicine, ...	$C_{17}H_{19}NO_5$	Soluble.	S.	S.S.	S.	S.	Colchicum autumnale.
Coniïne, ...	$C_8H_{17}N$	In 100 pts.	S.	S.	S. in 6 pts.	S.	Water hemlock. Conium maculatum.
Delphinine, . . .	$C_{24}H_{35}NO_2$	Insol.	S.	S.	S.	S.	Delphinium staphisagria.
Emetine, ...	$C_{28}H_{40}N_2O_5$	S.S.	S.S.	S.	Nearly Insol	S.	Ipecacuanha.
Ergotine, ...	$C_{50}H_{52}N_2O_3$	S.	. .	. .	Insol.	Insol.	Ergot of rye.
Hydrastine, . . .	$C_{21}H_{21}NO_6$	Insol.	S.S.	. .	S.S.	S.	Hydrastis canadensis.
Hyoscine, ...	$C_{17}H_{23}NO_3$	S.	. .	. .	. .	. .	. . .
Hyoscyamine, . .	$C_{15}H_{23}NO_3$.	S. in hot.	S. in hot.	S.	S.	S.	Hyoscyamus niger.
Morphine, ...	$C_{17}H_{19}NO_3H_2O$	S. in 500 pts. boiling.	S.S.	Insol.	Insol.	S. in 50 pts.	Opium.
Narceine, ...	$C_{23}H_{29}NO_9$	S. in 200 pts. boiling.	S.S.	S.S.	Insol.	S.S.	Opium.
Narcotine, ...	$C_{22}H_{23}NO_7$	S. in 7000 boiling.	Insol.	S. in 25 pts.	S. in 120 pts.	S. in 3 pts.	Opium.
Nicotine, ...	C_5H_7N	S.	S.	S.	S.	S.S.	Tobacco (tabacum).
Papaverine, . . .	$C_{21}H_{21}NO_4$	Insol.	Insol.	S. in 40 pts.	S.S.	S.	Opium.

NATURAL ALKALOIDS.—*Continued.*

NAME.	FORMULA.	SOLUBLE IN WATER.	AMMONIA WATER.	BENZENE.	ETHER.	CHLOROFORM.	SOURCE.
Physostigmine (Eserine),	$C_{15}H_{21}N_3O_2$	S.S.	S.S.	S.	S.	S.	Calabar bean.
Pilocarpine, ...	$C_{11}H_{16}N_2O_2$	S. del.	S.S.	. .	Insol.	Insol.	Jaborandi.
Piperine, ...	$C_{17}H_{19}NO_3$	Nearly Insol.	. .	S.	S. in 90 pts.	S.	Cayenne pepper.
Piperidine, ...	$C_5H_{11}N$	S.	S.	S.	. .	. .	Piperine.
Pseudomorphine, . .	$C_{17}H_{19}NO_4$	Insol.	Insol.	. .	Insol.	Insol.	Opium.
Quinine, ...	$C_{20}H_{24}N_2O_2 \cdot 3H_2O$	S. in 1800 pts.	S.S.	S.	S.	S. in 50 pts.	Cinchona bark.
Quinidine, ...	$C_{20}H_{24}N_2O_2$	S. in 750 pts.	. .	S.	S. in 30 pts.	S.	Cinchona bark.
Rhœadine, ...	$C_{21}H_{21}NO_6$	Insol.	Insol.	S.S.	S. in 1300 pts	S.S.	Opium.
Sparteine, ...	$C_{15}H_{26}N_2$	S.S.	. .	. .	. .	. .	Broom corn.
Strychnine, ...	$C_{21}H_{22}N_2O_2$	S. in 6500 pts.	S.S.	S. in 160 pts.	Insol.	S. in 7 pts.	Nux vomica.
Thebaine, ...	$C_{19}H_{21}NO_3$	Insol. (cold).	Insol.	S. in 18 pts.	S.	S.S.	Opium.
Theobromine, ...	$C_7H_8N_4O_2$	S. in 750 pts.	S.	S.S.	Nearly Insol	S.S.	Cocoa nuts.
Veratrine, ...	$C_{37}H_{53}NO_{11}$	S. in 1000 pts. hot	S.S.	S.	S. in 12 pts.	S. in 2 pts.	Veratrum alba.

GLUCOSIDES.

NAME.	FORMULA.	SOLUBLE IN WATER.	AMMONIA WATER.	BENZENE.	ETHER.	CHLOROFORM.	SOURCE.
Daphnin, ...	$C_{31}H_{34}O_{19}$	S.S.	S.	. .	Nearly Insol	. .	Several species of daphne.
Digitalin, ...	$C_{10}H_{16}O_4$	S.S.	S.	S.	S.S.	S.S.	Foxglove (digitalis).
Picrotoxin, ...	$C_{30}H_{34}O_{13}$	S. in 50 pts.	S.	S.	S. in 250 pts.	S.	Cocculus indicus.
Salicin, ...	$C_{13}H_{18}O_7$	S.	. .	Nearly Insol	Insol.	. .	Willow leaves.
Solanin, ...	$C_{43}H_{69}NO_{16}$	S. in 8000 hot.	Insol.	S.S.	S. in 4000 pts	Insol.	Bittersweet.
Saponin, ...	$C_{32}H_{54}O_{18}$	S.	S.	. .	Insol.	. .	Saponaria officinalis.

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* Largely from Prescott's "Prox. Organic Anal."

EXPLANATION.—S., soluble; S.S., slightly soluble. The numbers indicate the quantity of water required to dissolve one part of alkaloid.

NON-VOLATILE ALKALOIDS.

Properties of the Principal Non-volatile Alkaloids. —**Aconitine.**—It is a glacial mass, or white powder, and crystallizes with difficulty in rhombic plates. It possesses a sharp, pungent taste, and, in general, the physiological properties of the plant.

The commercial alkaloid is probably a mixture of several alkaloids, of which aconite root contains at least nine. The alkaloid is very poisonous, and care should be exercised in tasting it. The most characteristic test is the numbness of the tongue and lips which it produces in from one to fifteen minutes after tasting it. This numbness suffices to detect as small a quantity as .01 of a milligramme of the alkaloid. It neutralizes acids, forming crystalline salts. It is precipitated from its aqueous solutions by alkalies, phosphomolybdic acid, Mayer's reagent, and by iodine in Kl solution. It is not pptd. by $PtCl_4$, $HgCl_2$, or picric acid.

Apomorphine, $C_{17}H_{17}NO_2$. When morphine is heated to 110° C. (230° F.) with an excess of HCl and zinc chloride, it is converted into apomorphine hydrochlorate.

Apomorphinæ Hydrochloras, U. S. P., forms minute grayish-white, bitter crystals, becoming greenish on exposure to light, It is soluble in water and alcohol, and slightly soluble in ether and chloroform. It can also be prepared in the same way from codeine

Atropine—Daturine—Atropina (U. S. P.)—occurs in belladonna and stramonium. It crystallizes in prisms, or stellated tufts, white and fusible. It has a bitter taste, and dilates the pupil, either when free or as salts. It is odorless. It is distinctly alkaline, and neutralizes acids forming crystalline salts. **Atropinæ sulphas** is official, and appears as a white, crystalline powder, soluble in water. It is an active poison producing dryness of the throat, flushing of the face, dilatation of the pupils, loss of speech and of muscular power, dizziness, delirium, and coma Fatal cases of poisoning are not frequent. The treatment should consist in removing the unabsorbed drug with the stomach tube, after the administration of some liquid containing tannin, as tea A solution of atropine dropped into the eye of a cat dilates the pupil. This is used as a test for the alkaloid.

Atropine belongs to a series of compounds called **tropeïnes,** and is isomeric with hyoscyamine and hyoscine.

The other natural tropeïnes are belladonnine, atropamine, scopolamine, and benzoyl-pseudotropine. They are all saponifiable by treatment with acids or alkalies, and are split into an acid, generally tropic acid, $C_6H_5C(CH_2)COOH$, and tropine, or pseudotropine, $C_5H_7(C_2H_4OH)N.CH_3$

Brucine, $C_{23}H_{26}N_2O_4.4H_2O$, accompanies strychnine in the seeds and bark of different varieties of *strychnose*, or nux vomica. It forms oblique prisms or plates, sparingly soluble in water, readily soluble in alcohol, chloroform, and amyl alcohol, which readily lose their water when dried in the air. It is intensely bitter and has a strong basic reaction, forming crystalline salts. Its action in the economy is similar to that of strychnine, but less active. With strong nitric acid it gives a red, fading to yellow, color; $SnCl_2$ changes the above red color to violet. Chlorine water colors it a bright red, which is changed to yellow brown by NH_4OH.

Caffeine — Theine — Guaranine — Caffeina (U. S. P.), $C_8H_{10}N_4O_2 + H_2O$. White silky needles; fuses and sublimes; has a faint bitter taste; poisonous in large doses; 0.4 to 0.5 gr. produces death in cats and rabbits. It exists in coffee, tea, and some other plants. Hot, fuming HNO_3 turns it yellow, which, after evaporation and treatment with NH_4OH, becomes purple.

Caffeine Citrate—Caffeina Citrata (U. S. P.), is defined as a weak compound of caffeine and citric acid, but it is probably a mere mechanical mixture.

It is a white powder having an acid taste and reaction. It is soluble in about 25 parts of water. Its physiological properties are the same as those of the alkaloid.

Cinchona Alkaloids.—Cinchona bark contains a considerable number of alkaloids, several of which are employed in medicine. No less than 33 of these alkaloids have been isolated. They exist chiefly, though not wholly, in the bark and are remarkable for their valuable antiperiodic and febrifuge properties. They all have well-defined basic characters, and their salts are usually crystallizable. Their basic character is such that they may be estimated by titration with a standard acid. They are but slightly soluble in water, but dissolve more readily in alcohol, and very easily in ether and chloroform. The latter liquids will remove them from ammoniacal solutions by agitation, but will not from a solution acidulated with H_2SO_4 or HCl. A solution of these alkaloids in H_2SO_4 exhibits a characteristic strong blue fluorescence. They are precipitated by the fixed alkalies, alkaline carbonates, or ammonia. The most important cinchona alkaloids are: Quinine, Quinidine, Cinchonine, and Cinchonidine.

Quinine—Quinia—Quinina (U. S. P.) – $C_{20}H_{24}N_2O_2\ 3H_2O$, exists in the bark of the various species of the cinchona growing in the mountains of the northern part of South America. Different samples of the cinchona bark vary in the richness of alkaloids. They vary from 33 per cent. to as low as 5 per cent. It occurs as a white, flaky, amorphous, or crystalline powder, permanent in the air, and having a very bitter taste. It is soluble in 1670 parts of water and in six parts of alcohol. It is also soluble in chloroform, ether, carbon disulphide, benzene, ammonia water, and dilute acids. When treated at 100° C. (212° F.) it loses a part of its water of crystallization, but the remainder is expelled at 125° C. (257° F.). It has an alkaline reaction upon litmus paper, brazil wood, or methyl-orange.

A sulphate, bisulphate, hydrobromate, hydrochlorate, and valerianate are official. The tannate, salicylate, phenate, and numerous other salts are also employed in medicine.

Quinine Sulphate—Quininæ Sulphas (U. S. P.) – $(C_{20}H_{24}N_2O_2)_2H_2SO_4.7H_2O$, is manufactured on a large scale for use in medicine. It is found in white, silk-like, needle-shaped crystals, somewhat flexible, making a very light and easily compressible mass, which effloresces in dry air, absorbs water in moist air and becomes colored on exposure to light. It has a persistent, very bitter taste, and is not very soluble in water, but more readily in alcohol. It is soluble in 740 parts of water, 65 parts of alcohol, 40 parts of glycerin, and is freely soluble in dilute acids. When exposed to the air at a temperature of 100° C. (212° F.) for some hours, it loses all of its water of crystallization. The solution, especially in excess of H_2SO_4, exhibits a vivid blue fluorescence. The alkaloid is precipitated on the addition of ammonia water, but the precipitate is soluble in excess of ammonia. On treating 10 c. c. of an aqueous solution of the salt with two drops of bromine water, and then with an excess of ammonia water, the liquid assumes an emerald green color.

Quinine Bisulphide—Acid Quinine Sulphate—Quinine Bisulphas (U. S. P.) — $C_{20}H_{24}N_2O_2H_2SO_4.7H_2O$, occurs as colorless, transparent, or whitish crystals or small needles, odorless, and having a very bitter taste. They are freely soluble in water, exhibiting beautiful blue fluorescence. It loses all of its water of crystallization at 100° C. (212° F.). It gives the same reaction with bromine water and ammonia as the sulphate.

Solution of iodine precipitates from the acetic acid solution of the basic sulphate, a tourmaline-like, crystalline body with a green reflection.

The solutions of quinine and its salts are lævorotatory. When dissolved in chlorine water, ammonium hydrate produces a deep emerald-green solution. If K_4FeCy_6 be first added, NH_4OH gives a deep red color.

Quinine Hydrobromas, $C_{20}H_{24}N_2O_2HBr.H_2O$, **Quininæ Hydrochloras,** $C_{20}H_{24}N_2O_2HCl.2H_2O$, **Quininæ Valerianas,** $C_{20}H_{24}N_2O_2C_5H_{10}O_2.H_2O$, are official. They occur as white, lustreless, silky needles, odorless and having a very bitter taste.

Quinidine and **Quinicine** are isomeric with quinine and are found with it. Quinidine is distinguished from quinine by its strong dextrorotatory power. Quinicine is produced by the action of heat upon quinine, and does not exist in the bark. Quinidine occurs in large prisms, soluble with difficulty in water, but soluble in alcohol. It gives the same reaction as quinine with chlorine and ammonia. It has a bitter taste and tonic properties similar to quinine, and its salts resemble those of quinine. It is dextrorotatory. The sulphate is official.

Cinchona—Cinchonine—Cinchonina (U. S. P.)—$C_{19}H_{22}N_2O$, occurs in cinchona bark, together with quinine and the other alkaloids. It occurs in four-sided needles, fusing at 150° C. (302° F.). It is soluble in 3810 parts of water and 140 parts of alcohol. Its solutions are dextrorotatory; chlorine and ammonia give yellow precipitates; separated from quinine by insolubility in ether; very bitter and has less tonic properties than quinine. The sulphate is official also.

Cocaine, $C_{17}H_{21}NO_4$, is one of the nine alkaloids which occur in the leaves of *Erythroxylon coca*. It occurs in monoclinic, glistening prisms. Heated with strong HCl, it decomposes The hydrochlorate has powerful anæsthetic properties. Coca leaves are used in Peru as a stimulant. Its taste is at first bitter, producing paralysis of the sense of taste and a consequent numbness of the tongue. When heated with strong HCl, it decomposes into benzoic acid, methyl alcohol, and **ecgonine,** $C_9H_{15}NO_3$, a new base. Cocaine has been prepared synthetically from ecgonine.

The hydrochlorate, $C_{17}H_{21}NO_4HCl$ (**cocainæ hydrochloras,** U. S. P.), is the only official salt. It occurs as colorless, transparent crystals, having a bitterish saline taste, and producing on the tongue a tingling, benumbing sensation lasting for some minutes. It is soluble in water and alcohol, but is soluble with difficulty in ether. It is used externally as a local anæsthetic, especially on the mucous membranes, and also internally.

Owing to its stimulant and exhilarant properties, cocaine is sometimes employed as a stimulant, and occasionally cases of the cocaine habit are met with, which is often more demoralizing than the morphine habit.

Colchicine, $C_{21}H_{22}(CH_3O)NO_5$, occurs in *Colchicum autumnale* and in other plants of the same family. It is a yellow-white, gummy, amorphous substance (usually amorphous), with a melting point of about 147° C. (296° F.). It is readily soluble in water, alcohol, and chloroform. It is employed, like the plant, in the treatment of rheumatism and gout in doses from $\frac{1}{120}$th to $\frac{1}{20}$th gr. By the process of hydrolysis, this alkaloid yields a second one called

Colchiceine, $C_{21}H_{22}OHNO_5$.—This substance is readily soluble in boiling water, alcohol, and chloroform, and but slightly soluble in cold water. It is occasionally employed in medicine.

Hyoscyamine, $C_{17}H_{23}NO_3$, is an alkaloid occurring in belladonna and hyoscyamus. It is isomeric with atropine, and is easily converted into it. It occurs as yellow-white, amorphous, resinous-like masses, or as prismatic crystals, having, particularly when damp, a tobacco-like odor, and an acrid, nauseous, bitter taste. It is deliquescent on exposure to the air. It is very soluble in water and alcohol, and almost insoluble in ether. It dilates the pupils, like atropine, and possesses sedative properties.

Hyoscyaminæ Sulphas, $(C_{17}H_{23}NO_3)_2H_2SO_4$, and **Hyoscyaminæ Hydrobromas,** $C_{17}H_{23}NO_3HBr$, are official.

Hyoscine, $C_{17}H_{21}NO_4$. is another alkaloid obtained from hyoscyamus. **Hyoscine hydrobromate** is official. It occurs in colorless, transparent, rhombic crystals, soluble in water and alcohol. Its solution has a bitter, slightly pungent taste. It is employed as a sedative and hypnotic, and is especially used in mania and neuralgia. It is more active and rapid in its effects than either atropia or hyoscyamine.

Opium and its Alkaloids.—Opium is a concrete, milky exudation of the unripe capsules of the **Papaver somniferum,** or Poppy. It is, chemically, a mixture of a large number of substances, containing gum, albumin, wax, volatile and coloring matters, meconic acid, meconin, and no less than 16 or 18 alkaloids, the most important of which are morphine and codeine.

The value of opium in commerce is generally determined by an assay for the quantity of morphine present in it. Ordinary opium should not contain less than 9 per cent. of morphine, and when dried at 85° C. (185° F.) it should contain from 12 to 16 per cent. of this alkaloid, when estimated according to the method of the U. S. P.

Opium occurs in the market in irregular or globular masses, with the remnant of poppy leaves adhering to the surface. It is usually plastic in consistency, of a dark-brown color, and a somewhat shining appearance. It has a nauseous, peculiar, bitter taste. When the gum is dried, powdered, and exhausted with ten times its own weight of strong ether, the ethereal solution separated, and sugar of milk added to restore the original weight, it forms the denarcotized opium of the U. S. P. The principal alkaloid of opium is morphine.

Morphine—Morphinæ (U.S.P)—$C_{17}H_{19}NO_3$. It occurs in short, transparent, trimetric prisms, odorless, very bitter, and fusing at 120° C. (248° F.). Morphine is soluble in hot water, alcohol, and amyl alcohol, but nearly insoluble in cold water and only slightly soluble in cold alcohol and amyl alcohol. It gives a blue color with neutral solutions of Fe_2Cl_6; it decomposes iodic acid, giving free iodine. Its solutions are lævorotatory. It is especially noted for its anodyne properties.

Morphine dissolves readily in dilute acids, forming very soluble and crystallizable salts, the most important of which are the official sulphate, hydrochlorate, and acetate. When heated with large excess of HCl, it gives **apomorphine,** $C_{17}H_{17}NO_2$, which is precipitated as a white powder by sodium carbonate, and turns green on exposure to the air. It is said to be formed spontaneously in old morphine solutions. The hydrochlorate is a speedy, non-irritant emetic.

Physostigmine—Eserine—Physostigma, $C_{15}H_{21}N_3O_2$, is an alkaloid obtained from the Calabar bean, *Physostigma venenosum.* It is a crystalline or amorphous brown-yellow powder. Its solutions vary in color from red to blue, and are strongly alkaline in reaction. It is a violent poison and strongly contracts the pupils. The salicylate, occurring in crystalline prisms, and the sulphate, a yellow-white crystalline powder, are official.

Picrotoxine, $C_{30}H_{34}O_{13}$, colorless, lustrous, bitter needles, obtained from the fruit of *Anamirta paniculata.* It reduces alkaline copper solutions. It has an intensely bitter taste, and is soluble in alcohol and in water. It is employed in medicine. It is official.

Piperine, $C_{17}H_{19}NO_3$, is the alkaloid of pepper. It crystallizes in colorless, tasteless, inodorless prisms, melting at 130° C. (266° F.). The alcoholic solution has a sharp, peppery taste and neutral reaction. It is soluble in alcohol, but almost insoluble in water.

Pilocarpine, $C_{11}H_{16}N_2O_2$, is the principal alkaloid of Jaborandi. It is uncrystallizable, but its salts crystallize from alcohol. With H_2SO_4 it forms a colorless solution. The nitrate and hydrochlorate are much used in medicine. Given internally, they produce rapid and profuse diaphoresis and salivation, quickened pulse, and lowered temperature. With large doses, the heart stops in diastole. The hydrochlorate—**Pilocarpinæ hydrochloras** (U. S. P.), is official. It occurs as small, white, odorless crystals, having a slightly bitter taste, very soluble in water or alcohol. It is deliquescent.

Strychnine, Strychnina, U. S. P., $C_{21}H_{22}N_2O_2$, exists in the seeds and bark of *nux vomica*, and in the seeds of *Strychnos ignatiæ*, "St. Ignatius' bean," and other plants of the same family. It crystallizes in white, fusible, four-sided trimetric prisms. Its bitter taste can be detected in a solution containing one part in one million parts of water. It forms soluble crystalline salts, and is a violent poison, producing tetanic convulsions. The physiological antidotes are morphine, atropine, and chloral hydrate. A delicate **test** is to dissolve the suspected substance in sulphuric acid and add a fragment of potassium dichromate, when a deep purple-red color is produced if strychnine is present.

The British Pharmacopœia does not recognize any of the salts of strychnine. In Germany, the nitrate is official, and in the U. S. P., the sulphate, which is used largely in medicine. The phosphate and nitrate are also used in this country.

Theobromine, $C_7H_8N_4O_2$, occurs in the seed or bean of *Theobroma cacao*. It closely resembles caffeine in its physiological action. It is eliminated by the kidneys, and can be detected in the urine. It forms small, white, trimetric crystals, sparingly soluble in water, alcohol, and ether. It has a slightly bitter taste. The salicylate of theobromine and sodium is used under the name of **duretin.** Salts are unstable and decompose in contact with water.

Veratrine, $C_{30}H_{46}N_2O_8$, occurs in *Asagræa officinalis*. White prisms or powder, melting at 175° C. (347 F.) and solidifying, on cooling, to a resinous mass. Its dust causes violent sneezing; it is a violent poison. Concentrated H_2SO_4 forms a yellow solution which gradually becomes red. It forms crystalline salts. The oleate and an ointment of veratrine are official.

PTOMAINES.

Putrefactive, or Cadaveric Alkaloids.—These alkaloids are produced during the putrid decomposition of animal and vegetable matter, and probably in certain pathological conditions in the human body during life. They are the result of the growth of the bacteria that produce the decomposition of dead animal and vegetable tissue.

Some of these bases are very poisonous, producing symptoms resembling those caused by strychnine, atropine, coniïne, etc. Selmi obtained poisonous bases containing arsenic from the body of a subject who had died of arsenical poisoning, and was exhumed fourteen days after death. It is probable that the symptoms of poisoning by preserved foods such as canned fish, meat, etc., that are occasionally seen, are due to the presence of some one of these alkaloids. Tainted meat, fish, etc., should not be eaten. The author has known of a number of cases of poisoning from this cause.

Some of these alkaloids decompose with great ease, giving a cadaveric odor, while others remain permanent. Although they are most likely to be found in putrefying animal matters, they have been produced by the putrefaction of maize, leguminous substances, flour, etc. Many of the ptomaines are volatile and amorphous, but form crystalline salts with the acids. They answer to nearly all the ordinary reactions of the vegetable alkaloids. They seem to possess less stability, and generally have a greater tendency to undergo oxidation than the vegetable bases, and hence frequently act as reducing agents. The ptomaines are formed during the earlier stages of the putrefactive processes, and as putrefaction progresses they gradually disappear and give place to well-known aromatic or benzénoid compounds. Brieger found that there are produced at first oxygenated bases, like choline, muscarine, neurine, gadinine, and tetanine.

These seem to disappear afterward and amins take their places, such as dimethylamin, trimethylamin, triethylamin, putrescin, cadaverin, saprin, neuridin, collidin, hydrocollidin, parvolin, and tyrotoxicon (diazobenzene). Some of these are volatile and others decompose on the application of heat, especially on evaporation to dryness.

The number of these alkaloids that have been isolated is considerable. Some of them have not been sufficiently studied to determine their constitution. Some of these bases so closely resemble the vegetable alkaloids, that they have been mistaken for the latter by chemists. The alkaloids likely to be confounded with ptomaines are conine, nicotine, strychnine, morphine, atropine, digitaline, veratrine, delphinine, and colchicine. Not only do the ptomaines have many reactions that have been heretofore regarded as characteristic of the above-named alkaloids, but their presence in some cases prevents the detection of certain alkaloids by the usual reagents. These facts have a very important bearing upon the toxicological search for the alkaloids. Indeed, serious mistakes have been made by chemists who have had charge of such analyses, owing to imperfect knowledge of these putrefactive alkaloids.

The separation of the ptomaines from the vegetable alkaloids is attended with great difficulty. Tamba states that the oxalates of the vegetable alkaloids are precipitated from solutions of mixtures in ether, while the oxalates of the ptomaines are soluble. That is, if to an ethereal solution of the alkaloids, an equal volume of a saturated solution of oxalic acid in ether be added, the oxalates of the vegetable alkaloids separate out on standing, while the ptomaines remain in solution. Cadaverin is said to precipitate along with the vegetable alkaloids. Another somewhat distinctive reaction for the ptomaines is their reducing action upon potassium ferricyanide. If a solution containing ferric chloride and potassium ferricyanide be treated with a drop or two of a solution containing a ptomaine, the ferricyanide is reduced to ferrocyanide which gives an immediate precipitate of Prussian blue with the ferric chloride. The only vegetable alkaloids thus far known to reduce ferricyanides are morphine and veratrine.

Physiological Action of Ptomaines.—The cadaveric alkaloids are not all toxic. Of those which are, there is a great variation in the degree, as well as in the symptoms produced. The free ptomaines are more energetic than their salts. The principal symptoms observed in dogs are the following: 1st, dilatation of the pupil, followed by contraction, sometimes irregular contraction of the pupils; 2d, paralysis of the vasomotor nerves, causing an increased cutaneous heat and injection of the helices of the ears; 3d, diminished or slowing of the respiration; 4, somnolence, followed by convulsions and death; 5th loss of muscular contractility to electric stimulus.

The symptoms in man, although varied by the character of the poison and the condition of the individual at the time, are generally those of a powerful gastro-intestinal irritant. There is usually a period of incubation of from two to six hours. With a given article of food containing ptomaines (undergoing putrid fermentation) there is frequently a remarkable agreement in this period of incubation in different persons, the symptoms in all beginning within a few minutes of the same time. There is usually sudden and severe retching with abdominal pain, prostration, disturbed circulation, and often delirium. There is sometimes dilatation of the pupil and redness of the skin, or a fine scarlatinal-like eruption. Thirst is usually intense. Diarrhœa is frequent, but not always present; the discharges are very offensive. Muscular twitchings and even convulsions may be met with. There is a tendency to collapse, which must be guarded against. The temperature is in some cases elevated, and in others below normal.

The above description applies to the symptoms of ptomaine poisoning as usually met with in cases of poisoning by putrid or decomposing food, and not to the individual ptomaines. While the poisonous properties of some ptomaines are well marked, in others they are more or less wanting. The poisonous ptomaines are sometimes called *toxins*, in order to distinguish them from the non-poisonous ones. The term toxin, however, is more frequently applied to poisons produced by bacterial action, without definite knowledge as to whether it be a ptomaine or toxalbumin. Among the non-poisonous ptomaines are a number of the amin bases which may be formed by other processes than putrefaction. Among these may be mentioned methylamin, dimethylamin, trimethylamin, ethylamin, diethylamin, triethylamin, propylamin, neurodin, most of which have been mentioned among the amins. Among the amins may be mentioned mydin, $C_8H_{11}NO$, pyrocyanin, $C_{14}H_{14}NO_2$, and betaine, $C_5H_{13}NO_3$.

The most important of the poisonous ptomaines are the following:—

Cadaverin, $C_5H_{14}N_2$, occurs very frequently in decomposing animal tissue. It is not very poisonous, but is capable of producing intense inflammation and suppuration, even in the absence of bacteria. It appears late in the putrefactive process, but readily in cultivations of the cholera bacillus, and the Finckler-Prior vibrio. It belongs to the diamins and is chemically pentamethylen-diamin. It is a syrupy liquid, possessing an unpleasant odor resembling that of coniïne.

Cholin, $C_5H_{15}NO_2$, is similar in properties to neurin, and has been already mentioned among the organic bases.

Muscarin, $C_5H_{13}NO_2$, was first discovered in poisonous mushrooms, *Agaricus muscarius*. It has also been obtained by the oxidizing action of HNO_3 on cholin. It is closely related, therefore, to this base. It has been obtained also from putrid fish. It is a very active poison, acting upon the muscular tissue itself, especially of the heart. It is antagonistic to atropine in its action upon the heart. Atropine may, therefore, be regarded as its physiological antidote.

Neurin, $C_5H_{13}NO$, is a syrupy base of strong alkaline reaction, and has been obtained synthetically by boiling protagon from brain substance with baryta, and by other synthetic processes. It is a constant product of cadaveric putrefaction, and is a more powerful toxic agent than cholin, with which it is usually associated. Atropine is its physiological antagonist, and its poisonous symptoms may frequently be dispelled by a hypodermic injection of a small dose of this alkaloid.

Cholin, muscarin, and neurin usually occur together. They are all active poisons; cholin and neurin acting like curara; muscarin acting on the muscular tissue itself. They are all antagonized by atropine, so far as relates to their action on the heart. They are usually present in the putrefaction of proteids, and are often concerned in producing the symptoms seen in cases of poisoning by putrid meats.

Gadinin, $C_7H_{16}NO_2$, has been obtained from putrefying codfish.

Mytilotoxin, $C_6H_{15}NO_2$, is the active agent in poisonous mussels.

Typhotoxin, $C_7H_{17}NO_2$, is an alkaloid which has been obtained from pure cultures of the bacillus of typhoid fever, and is supposed to be the chemical poison concerned in producing the symptoms in this disease.

Typhotoxin, when injected into the circulation of animals, produces a lethargic or paralytic condition, in which the animal falls down helpless. Frequently diarrhœal evacuations take place, and death follows in from one to two days.

Tetanin, $C_{13}H_{30}N_2O_4$, is supposed to be the chemical poison in cases of tetanus. It produces in animals the characteristic symptoms of tetanus, such as tonic and clonic convulsions.

Tyrotoxicon, $C_6H_5N_2$, is a poison which has been separated from poisonous cheese, ice-cream, and milk. Its true chemical composition has not yet been established. It is supposed to be the active agent in producing the symptoms usually seen in cases of cheese poisoning.

Putrescin, $C_4H_{12}N_2$ (**tetramethyldiamin**), is usually found accompanying cadaverin, but makes its appearance much later. It is found together with cadaverin in fæces and urine. It is a poison, but not very virulent.

The symptoms produced by it are very similar to those of cholera, but the muscular cramps and other symptoms produced in cholera are probably caused by other poisonous substances.

TOXINS.

Poisonous Proteids and Allied Poisons.—Protein substances readily undergo decomposition under the influence of the growth of various micro-organisms. Some of these decomposition products, when introduced into the circulation, are poisonous. The poisonous proteids are not easily distinguishable by chemical or physical properties, from non-poisonous or food proteids. The most important of the vegetable proteid poisons are those contained in the seeds of **Jequirity,** that associated with papain, and that from *lupinus luteus*.

The most important of the animal poisons are, snake poison, the proteids in the serum of the conger eel, that found in certain spiders, and under certain conditions albumoses, and peptones. In the case of snake poison, no bacteria seem to be present, and the proteids, separated in the pure condition, are as poisonous as the original venom. The venom of the cobra and viper, according to the most recent analyses, are found to contain globulin, albumin, and syntonin in the former, and globulin, albumin, and albumoses in the latter, all of which are poisonous. The chief symptom produced is asphyxia. The disease-producing bacteria form, as a result of their growth, certain substances which are more or less poisonous. Pure cultures of the anthrax bacillus produce a substance which, if inoculated into animals, renders them immune from anthrax. This principle is believed to explain the cause of immunity in animals who have suffered from certain specific diseases. The immunity of animals who have suffered from a contagious disease is supposed to be due to the production of these products of the growth of the specific micro-organism of that disease, and immunity may be produced by injecting these products. Most specific organisms produce a toxin, or poison, and an antitoxin, or protective principle. It does not, however, appear that in all cases two substances are necessarily formed. The bacillus of diphtheria has been shown to produce a proteid which, when injected into animals, produces diphtheritic symptoms. These proteids obtained from bacterial growth have been named toxalbumins They appear, however, to be an active form of albumose rather than albumin. Other poisonous proteids have been obtained from cultures of the bacilli of tetanus, cholera, typhoid fever, and cholera infantum. The proteids found in the latter case are usually highly poisonous when injected under the skin of dogs or other lower animals, producing vomiting, purging, collapse, and death. Koch's **tuberculin** is the impure toxalbumin, or albumose, resulting from the growth of the tubercular bacillus in pure cultures.

Tuberculocidin is the purified albumose which is used in the treatment of tuberculosis. The amount employed is said to be about ⅓ grain per day.

Diphtheria Antitoxin is a clear, transparent serum obtained from the blood of an animal, usually the horse, which has been rendered immune by repeated injections of a pure culture of the diphtheria bacillus rendered sterile by filtration, and the addition of some antiseptic. It is supposed to contain the protective principle against the toxin of diphtheria, which has been developed by the horse during the immunizing process.

Protective serums have been prepared for cholera, tetanus, rabies, anthrax, and other diseases.

LEUCOMAINES.

This term is applied by Gautier to those alkaloidal or basic substances elaborated in the body during life. They are either the resul. of fermentative changes within the body, or of the natural physiological processes in the cells, or by retrograde changes in the nitrogenous tissues. Most of these alkaloids are deleterious to the subject when anything interferes with their oxidation or elimination. They are eliminated in part, at least, by the kidneys. They act especially upon the nerve centres, producing sleepiness, lassitude, or occasionally vomiting and purgation. Some of them produce a febrile condition, while others produce a lowered temperature. Some of them are to be found in the excreta, viz.: in the urine, fæces, perspiration, etc. Some are to be found principally in the muscles, saliva, brain, liver, spleen, and other glandular bodies. The quantity and character of the leucomaines vary with pathological conditions. The urinary leucomaines have received special study. Though scarcely to be found in certain normal urines, they are greatly increased in certain diseases, so that this fluid may at times become very poisonous when introduced into the circulation.

Without giving a detailed description of these bodies, we give the following list of names, formulæ, and sources of the principal leucomaines:—

The Xanthin Group of Leucomaines.—These are all closely related to uric acid, as will be seen by comparison of the formulæ. Most of them have already been described in a former chapter.

(Uric acid, $C_5H_4N_4O_3$).
Adenin, $C_5H_5N_5$, pancreas, spleen, kidneys, lymphatic glands.
Hypoxanthin, $C_5H_4N_4O$, spleen, muscles, urine, kidney, etc.
Guanin, $C_5H_5N_5O$, guano, liver, pancreas, lungs.
Xanthin, $C_5H_4N_4O_2$, urinary calculus, almost all tissues.
Heteroxanthin, $C_6H_6N_4O_2$, urine of man and dog.
Paraxanthin, $C_7H_8N_4O_2$, urine of man.
Carnin, $C_7H_8N_4O_3$, extract of meat.
Pseudoxanthin, $C_4H_5N_4O$, beef muscle.
Spermin, C_2H_5N, spermatic fluid, sputa of bronchitis, spleen.

The Creatinin Group of Leucomaines.—

Creatinin, $C_4H_7N_3O$, urine.
Creatin, $C_4H_9N_3O_2$, urine.
Xanthocreatinin, $C_5H_{10}N_4O$, muscle.
Crusocreatinin, $C_5H_8N_4O$, muscle.
Amphicreatinin, $C_9H_{19}N_7O_4$, muscle.

Some of these bodies are said to be poisonous, and it is suspected that uræmia and many of the nervous symptoms of dyspepsia are due to their action. There are probably many more of these substances than have been isolated. It is known that there are certain poisonous substances destroyed in the liver. There are certain poisons thrown out with the breath, the urine in certain diseases, the saliva of man and other animals, and in various other tissues and fluids. Much remains to be known of these substances.

THE GLUCOSIDES.

The **glucosides** are a class of compounds widely distributed throughout the vegetable kingdom. They may be resolved into a sugar and another compound by acids, alkalies or certain ferments. They are probably ethers of glucose, or a related sugar. They show a wide range of properties and composition. Solanin, for example, is a base, while others have a distinct acid reaction. They are usually soluble in water and alcohol. Most, but not all, of them reduce Fehling's solution. They are not decomposed, as a rule, by water, but are easily decomposed by heating with dilute H_2SO_4 or HCl. Many of them are optically active. A few of them occur in the animal body. Many of them are used in medicine. We can mention here but a few of the more important of these bodies.

Amygdalin, $C_{20}H_{27}NO_{11}$, occurs in bitter almonds, in the kernels of cherries, plums, apricots, and in the leaves of laurels. Extracted from almonds by boiling alcohol, and precipitated by adding ether, it is obtained as pearly scales. It crystallizes in prisms. When **emulsin** (the ferment of bitter almonds) is added, it splits up into hydrocyanic acid, HCN, benzaldehyde, C_6H_5COH, and glucose.

Arbutin, $C_{13}H_{16}O_2$, is extracted from leaves of Uva-Ursi. It is soluble in water, has a bitter taste, and is crystalline. Emulsin and diluted acids yield glucose and hydroquinone.

Antiarin, $C_{14}H_{20}O_5.2H_2O$.—It is the active principle of the arrow-poison of Java; crystalline, soluble in water and alcohol. It is obtained from the milky juice of *Antiaris toxicaria.*

Coniferin, $C_{16}H_{22}O_8$, occurs in the cambian layer of the *coniferæ* family, and crystallizes in stellate groups of prisms. Emulsion yields glucose and coniferyl alcohol. This latter, when treated with sulphuric acid and potassium dichromate, yields artificial **vanillin,** a body identical with that obtained from the vanilla bean. It is now manufactured on a considerable scale.

Convolvulin, $C_{31}H_{50}O_{16}$.—It is the active principle of jalap; a resinous mass, soluble in alcohol and alkalies. **Jalapin** exists with the above in jalap.

Digitalin is a poisonous substance existing in common foxglove; it forms an amorphous powder having an intensely bitter taste.

It is readily soluble in water and absolute alcohol. Three glucoside principles have been described as occurring in digitalis; **digitalein, digitonin, digitalin.** Digitalein, whose formula is $C_5H_8O_2$, occurs as a yellowish amorphous powder, freely soluble in water and alcohol. It is said to combine the properties of digitalin and digitoxin. Digitoxin, $C_{21}H_{33}O_7$, is a white crystalline body of a bitter taste, readily soluble in chloroform, but insoluble in water. When subjected to hydrolysis it does not yield sugar, but other products. It is used in medicine.

Esculin, $C_{21}H_{24}O_{13}$, and **Esculetin,** $C_9H_6O_4$, occur in the bark of the horse-chestnut tree; sparingly soluble in cold, more freely in hot water; are crystalline and have a bitter taste.

Fraxin, $C_{32}H_{36}O_2$, is found in the bark of the ash and horse-chestnut tree, and forms colorless, needle-like crystals, soluble in water, furnishing a bitter, fluorescent solution.

Glycyrrhizin, or **Liquorice-Sugar,** $C_{24}H_{36}O_9$, is the sweet principle of licorice. It is a yellow, amorphous powder, having a sweet, acrid taste. It is soluble in water and alcohol. Acids split it into glucose and *glycyrrhetin.*

Helleborin, $C_{36}H_{42}O_6$, is found together with **helleborein,** $C_{26}H_{44}O_{16}$, in the root of green hellebore. It is insoluble in water, and forms glistening needles. It is a powerful poison.

Indican, $C_{52}H_{62}N_2O_{34}$, occurs in all plants yielding indigo. It is a pale-brown, syrupy liquid, having a bitter taste. When allowed to ferment, or when treated with diluted acids, it forms indigo blue and indiglucin, a form of sugar. Indigo has been prepared synthetically from cinnamic acid, which may be prepared from toluene. A substance called indican is found in the urine, but this is not identical with plant indican.

Populin, $C_{20}H_{22}O_8$, occurs with salicin, in the bark and leaves of the aspen. It forms small prisms having a sweet taste. Boiled with barium hydroxide, it yields salacin and benzoic acid.

Phlorizin, $C_{21}H_{24}O_{10} + 2H_2O$, occurs in the root bark of the apple, plum, pear, and cherry tree, and is soluble in alcohol. It is soluble in hot water, from which it crystallizes in silky needles having a bitter taste. Boiled with diluted acids, it yields glucose and **phloretin.**

Polychroite, $C_{48}H_{60}O_{18}$, is the coloring matter of saffron, and forms an amorphous, deliquescent, ruby-red mass.

Quercitrin or **Flavin,** $C_{27}H_{28}O_{12}$ occurs in tea, quercitron, sumach, grape-wine, catechu, etc. It is slightly soluble in water, soluble in alcohol, and forms small, yellow crystals, which may be partially sublimed in beautiful yellow needles. It is colored green by Fe_2Cl_6.

Salicin has already been described under Salicylic Acid, *q. v.*

Santonin—Santoninum (U. S. P.)—$C_{15}H_{18}O_3$, is a glucoside with acid properties obtained from various species of Artemisia. It crystallizes in colorless, tasteless, odorless, rectangular prisms, which turn yellow on exposure to the light. It is sparingly soluble in hot water, alcohol, and ether, and insoluble in cold water. Patients taking santonin, excrete the coloring matter by the urine, which assumes a yellow color, which, on treatment with an alkali, changes to cherry-red or crimson, this color being discharged by an acid. The coloring matter is also deposited in various other tissues, and when a patient is taking large doses, objects appear green from the staining of the tissue of the eye.

Saponin, $C_{32}H_{54}O_{18}$, occurs in *quillaia*, or soap tree bark, and other plants. It is soluble in water and alcohol. Its solution behaves like soap solutions. It is poisonous, but it is sometimes added to soda water to produce a permanent froth. Its dust causes sneezing.

Solanin, $C_{42}H_{87}NO_{16}$, occurs in sprouted potatoes. It is a glucoside; soluble in alcohol, nearly insoluble in water, and forms gum-like salts.

Strophanthin, $C_{20}H_{24}O_{10}$, is a glucoside obtained from strophanthus, in the form of white, bitter, crystalline plates; slightly soluble in water, soluble in alcohol, and insoluble in ether, carbon disulphide, or benzene.

The **Tannins** form a group of bodies found widely distributed in plants. These bodies are soluble in water, have an acid reaction, an astringent bitter taste, and form an insoluble compound with gelatin and albumin. They unite with animal skin, forming leather. With ferric salts, they form blue-black or green precipitates. They are used in the preparation of inks, in dyeing, and tanning.

Gallotannic Acid—Acidum Tannicum (U. S. P.)—C_{14}-H_9O_9H, occurs in oak bark, nutgalls, sumach, and some other plants, in considerable quantities. It may be extracted with a mixture of ether and alcohol. It is an amorphous, shining mass. Ferric salts give with it a bluish-black precipitate (ink); tartar emetic, a white one. It precipitates starch, gelatin, albumin, and most alkaloids. Its watery solution decomposes when exposed to the air for some time, yielding gallic and ellagic acids. Diluted mineral acids, when boiled with it, give gallic acid and glucose.

Quinic or **Quinotannic Acid,** $C_7H_{12}O_6$, occurs chiefly in cinchona barks as a salt of quinine, but is also found in the bilberry and coffee bean. It occurs as oblique, rhombic prisms. It is soluble in water. On dry distillation it yields, among other products, benzoic acid and phenol.

Other tannic acids are known, as **caffeetannic,** of coffee; **quercitannic,** of oak; catechutannic, of catechu; kinotannic, of kino, etc., which vary slightly in properties, according to their source.

PROTEIDS.

ALBUMINOUS COMPOUNDS.

This important class of bodies forms the chief part of the solid constituents of blood, muscle, lymph, glands and other organs of animals, and is also found in plants, principally in the seeds. They are the principal substances taking part in the physiological changes in the organism. They are mostly colloid (not crystalline), do not readily diffuse through animal membranes, and are very prone to decomposition. They all contain carbon, hydrogen, nitrogen and oxygen, while most of them contain sulphur in addition, and all contain some ash, mostly in the form of calcium phosphate. Independent of the ash, they have about the following composition :—

Carbon,	50 to 54	per cent.
Hydrogen,	6.7 to 7.6	"
Nitrogen,	13 to 18	"
Oxygen,	21 to 26	"
Sulphur,	0.4 to 1.6	"

GENERAL PROPERTIES OF THE PROTEIDS.

Solubility.—All proteids are insoluble in alcohol, some are soluble in water, others insoluble. Some of those insoluble in water are soluble in weak saline solutions. Some are insoluble in concentrated saline solutions, while others are soluble. All proteids are soluble with the aid of heat, in concentrated mineral acids, caustic alkalies, and acetic acid. Most of them are soluble in the gastric and pancreatic juices, but they undergo chemical change during solution.

Heat Coagulation.—Many of the proteids which are soluble in water or NaCl solutions, are rendered insoluble when these solutions are heated to near the boiling point. This precipitation is termed **coagulation.** The temperature at which the proteids coagulate is fairly constant for the same substance, and, as different proteids coagulate at different temperatures, this method may be employed for the separation of mixtures of different proteids. Unless in very concentrated solutions, they are not coagulated by heat in alkaline solutions, but are converted into alkali albumin. Acid albumin does not form so readily as alkali albumin, and hence slightly acidulated albumin solutions coagulate readily when heated. An excess of acid, however, dissolves the precipitate, thus forming an acid albumim. The temperature of coagulation of the different proteids varies between 73° and 84° C. (163.4° and 183.2° F.) for albumins, and between 56° and 75° C. (132.8° and 167° F.) for globulins.

All proteids which are coagulated by heating their solutions, come under two classes; the **albumins,** which are soluble in water and weak saline solutions, and the **globulins,** which are insoluble in water and soluble in weak saline solutions. All the proteids are lævorotatory. If pure and in solution, they may be detected and estimated by their specific rotatory power. The specific rotatory power of serum albumin is —56; egg albumin, —35; serum globulin, —59.7.

BEHAVIOR OF THE PRINCIPAL PROTEIDS WITH PRECIPITANTS.

NAME OF PROTEID.	SOLUBILITY IN WATER (COLD OR WARM).	TEMPERATURE OF COAGULATION.	WEAK SOLUTION OF NaCl (1 TO 5 %).	SATURATED SOLUTION OF NaCl OR $MgSO_4$.	SATURATION WITH $(NH_4)_2SO_4$.	ACETIC ACID WITH POTASS. FERROCYANIDE.	PURE HNO_3 (COLD).	ABSOLUTE ALCOHOL OR TANNIN WITH NaCl.	ACETIC ACID WITH 1, PICRIC ACID: 2, SODIUM TUNGSTATE, OR 3, POTASS. MERCURIC IODIDE.	SODIUM HYDROXIDE WITH COPPER SULPHATE.	COPPER SULPHATE.
Serum Albumin, ...	S.	73° C.	S.	Not pptd.	Pptd.	Pptd.	Pptd.	Pptd.	Pptd.	Violet.	. .
Egg "	S.	73° C.	S.	"	"	"	"	"	"	"	. .
Cell "	S.	73° C.	S.	"	"	"	"	"	"	"	. .
Muscle "	S.	73° C.	S.	"	"	"	"	"	"	"	. .
Lactalbumin, ...	S.	77° C.	S.	"	"	"	"	"	"	"	. .
Serum Globulin, ...	Ins.	75° C.	S. Pptd. on boiling.	Pptd.	Pptd.	Pptd.	S. Easily soluble in weak acids and alkalies.	Pptd.	Pptd.	Violet.	. .
Fibrinogen, ...	"	56° C.	S.	"	"	"	S.	"	"	"	. .
Globin, ...	"	. . .	S.	"	"	"	S.	"	"	"	. .
Myosinogen, ...	"	56° C.	S.	"	"	"	S.	"	"	"	. .
Myo globulin, ...	"	63° C.	S.	"	"	"	S.	"	"	"	. .
Vitellin, ...	"	75° C.	S.	Not pptd.	"	"	S.	"	"	"	. .
Crystallin, ...	"	73° C.	S.	"	"	"	S.	"	"	"	. .
Acid Albumin, ...	Ins.	Not at 100° C.	Ins.	Pptd.	Pptd.	Pptd.	Pptd.	Pptd.	Pptd.	Violet.	. .
Syntonin, ...	"	"	"	"	"	"	"	"	"	"	. .
Alkali albumin, ...	"	"	"	"	"	"	"	"	"	"	. .
Caseinogen, ...	"	"	"	"	"	"	"	"	"	"	. .
Proto-albumose, ...	S.	"	S.	Pptd.	Pptd.	Pptd.	Not pptd.	Pptd.	Pptd.	Rose Red.	Pptd.
Hetero albumose, ...	Ins.	Partly pptd. at 65° with NaCl	S.	" Soluble when hot.	"	"	"	"	"	"	"
Dutero-albumose, ...	S.	Not at 10 °.	S.	"	"	"	"	"	"	"	Not pptd.
Peptone, ...	S.	"	S.	Not pptd.	Not pptd.	Not pptd.	Not pptd.	Pptd.	Pptd. Sol. on heating	Rose Red.	Not pptd.

GENERAL REACTIONS OF PROTEIDS.

First. Heated with strong HNO_3, they and their solutions turn yellow, and deepen into an orange color on adding NH_4OH, NaOH, or KOH. (Xanthoproteic reaction). If proteids be present, except albumoses and peptones, a yellow precipitate is always obtained on adding the acid.

Second. Millon's reagent is prepared as follows: One part by weight of mercury and two of strong HNO_3 are mixed and gently warmed until the mercury is dissolved. The solution is diluted with twice its bulk of water, and the precipitate allowed to settle. The clear supernatant fluid is Millon's reagent. If a few drops of this solution be added to a solution of the proteids, a white precipitate occurs which, on heating, becomes a brick-red color. If they are present in only traces, no precipitate is obtained, but the solution is colored red.

Third. Add an excess of glacial acetic acid, and then concentrated H_2SO_4. A violet color with a feeble fluorescence is formed if proteids are present. This reaction is not delicate. (Adamkiewicz's reaction.)

Fourth. If albumin is precipitated with alcohol and washed with ether, it gives a deep violet color when heated with HCl. (Liebermann's reaction.)

Fifth. If mixed with an excess of a strong solution of NaOH, and one or two drops of a diluted solution of $CuSO_4$ be added, a violet color is obtained, which deepens in tint on boiling. (Piotrowski's reaction.)

In the case of albumoses and peptones, the color is rose-red with KOH, and reddish-violet with NH_4OH. This is also termed the *biuret* reaction.

The above tests serve to detect traces of pro'eids, and depend upon the development of colors. The following reactions depend upon the precipitation of the proteid from its solution.

Sixth. Make the fluid strongly acid with acetic acid and add a few drops of a solution of $K_4Fe(CN)_6$. The precipitate shows the presence of proteids, except peptones and some forms of albumose.

Seventh. Render the fluid strongly acid with acetic acid and add an equal volume of a concentrated solution of Na_2SO_4 and boil. This precipitates all proteids except peptones. This test is useful because it effects a very complete separation of proteids, except peptones, and the reagent employed does not interfere with other tests which are likely to be performed upon the solution, after the removal of the proteids by filtration. It is, therefore, useful to separate albumin from solutions before testing for sugar.

The following precipitate all proteids: Tannic acid in the presence of a faint excess of acetic acid; double iodide of mercury and potassium with a slight excess of HCl (Brucke's reagent); phosphotungstic acid in the presence of a considerable excess of HCl; excess of absolute alcohol in neutral or faintly acid solutions. Various neutral salts, more particularly ammonium sulphate and magnesium sulphate, have been employed for the precipitation and separation of the several proteids.

CLASSIFICATION OF THE PROTEIDS.

The proteids are conveniently classified as follows:—

Class 1. **Native Albumins.**—Soluble in H_2O; solution coagulated by heating, especially with diluted acids; not precipitated by alkaline carbonates or NaCl; *e. g.*, egg albumin (pptd. by ether), serum albumin (not pptd. by ether), cell albumin, muscle albumin, and lact-albumin.

Class 2. **Globulins.**—Insoluble in water; soluble in dilute NaCl solutions; soluble in very diluted acids or alkalies; with strong acids and alkalies rapidly changed into members of Class 3; readily precipitated by saturating their solutions with NaCl, $MgSO_4$, $(NH_4)_2SO_4$, and certain other neutral salts. Their solutions are precipitated by heat; *e. g.*, 1, crystallin, of the crystalline lens; 2, vitellin, from eggs; 3, serum globulin or para-globulin; 4, fibrinogen; 5, myosin; and 6, globin.

Class 3. **Derived Albumins,** or **Albuminates.**—Insoluble in distilled water and in dilute neutral saline solutions; soluble in acids and alkalies; neutral solutions not coagulated on boiling; *e. g.*, acid albumin, or syntonin, and alkaline albumin, caseinogen, anti-albumids, and glutenins.

Class 4. **Fibrins.**—Insoluble in water; difficultly soluble in strong acids and alkalies, and undergoing a simultaneous change into members of Class 3; soluble by the prolonged action of a 10 per cent solution of NaCl, changing into members of Class 2.

Class 5. **Coagulated Proteids.**—These are the products of the action of heat on members of the preceding classes, or of Class 3, when pptd. by neutralization and heat. They are also obtained by the prolonged action of alcohol in excess upon Classes 1, 2, and 4.

Class 6. **Albumoses** (proteoses or pro-peptones) and **Peptones.**—The peptones are very soluble in water; are not precipitated by acids, alkalies, neutral salts, or many other reagents which precipitate other proteids. They are precipitated by the prolonged action of strong alcohol, but not coagulated. They are readily diffusible.

The albuminoses are readily soluble in water, and are distinguished from the peptones, by being precipitated by saturation with neutral ammonium sulphate. They yield precipitates with many of the reagents which precipitate other proteids. A characteristic feature of the albumoses is, that the precipitate with HNO_3 and $K_4Fe(Cy)_6$, in the presence of acetic acid, disappears when the solution is warmed and reappears on cooling.

Class 7. **Compound Proteids** are those composed of a simple proteid united to some non-proteid body. This class includes the **mucins,** the **nucleins, nucleo-albumins,** and the compound globulins such as **hæmoglobin** and its derivatives.

Class 8. **Albuminoids,** or **Gelatinoids,** are bodies that are (*a*) either soluble in boiling water, yielding gelatin; (*b*) insoluble in boiling water, but slowly hydrated by boiling with dilute acids, and by pepsin-hydrochloric acid; (*c*) or, insoluble in boiling water, dilute acids, alkalies, and gastric or pancreatic juice.

Class 9. **Lardacein,** or **Amyloid Substances.**—Insoluble in water, diluted acids, and alkalies; and converted into albuminates by strong acids and alkalies.

ANIMAL PROTEIDS.

Serum Albumin exists in blood, chyle, lymph, and in small quantity in milk. In certain renal diseases it appears in the urine. When its solutions are heated to about 73° C. (163.4° F.), it coagulates to a flocculent precipitate, which, when dried, forms a compact amorphous mass.

Its solutions have a specific rotatory power of —56°. Strong mineral acids first precipitate it, then dissolve the coagulum. It is not precipitated by acetic acid alone, but when acidified with this acid, potassium ferrocyanide and ferricyanide coagulate it.

It may be obtained from blood serum by saturating it at 36° C. (96.8° F.) with $MgSO_4$, which precipitates the globulin. The filtrate is saturated with sodium sulphate at about 40° C. (104° F.), which precipitates the serum albumin, containing small quantities of salt. To obtain it pure, this precipitate is suspended in water and submitted to dialysis.

Pure serum albumin is a white, or pale yellow, amorphous substance, dissolving readily in water, forming a slightly alkaline, opalescent liquid, slowly coagulating at about 73° C. (163.4° F.). It is not precipitated by ether, and with difficulty by alcohol.

The following reagents may be used to detect its presence in solution: citric or acetic acid with potassium ferrocyanide, potassio-mercuric iodide, mercuric chloride, picric acid, concentrated nitric acid, or trichloracetic acid

Egg Albumin is found in the white of eggs, and differs from the above in being almost insoluble in nitric and hydrochloric acids, and is precipitated by alcohol and ether. Its specific rotatory power is less than that of serum albumin, being —35.5°.

The white of egg is a semi-fluid substance, situated between the shell and the ovum proper, or yolk. It is permeated by a network of fibrillated matter. This network is insoluble in hot water, dilute alcohol, and acetic acid. The liquid is alkaline in reaction, and especially rich in proteids, containing about 12.2 per cent. as a mean, varying considerably in different eggs from 11 to 13 per cent. It has the following composition: water, 82 to 88 per cent.; solids, about 13.3 per cent.; proteids, about 12.2 per cent.; sugar, about .5 per cent.; fats, alkaline soaps, lecithin, and cholesterin, about .66 per cent. (Lehman.)

The proteids of white of egg are: 1. Globulins, precipitated by dilute acetic acid, or by saturation with $MgSO_4$ or NaCl; 2. Albumins then remaining.

Vegetable Albumin occurs in small quantity in most vegetable juices. It shows the same general properties as the other albumins, but contains less sulphur.

THE GLOBULINS.

The **globulins** differ from the albumins in being insoluble in water, but soluble in sodium chloride solution (1 per cent.). Except vitellin, they are precipitated by saturated solutions of the same salt. They are soluble in very dilute HCl (1 part in 1000 being sufficient), with production of acid albumin.

Vitellin occurs in the yolk of egg. It is a white granular body, soluble in dilute NaCl solutions, and not precipitated by a saturated solution of the same. It coagulates at about 75° C. It dissolves readily in dilute acid ($\frac{1}{10}$ per cent.) and in alkalies. It is precipitated by alcohol.

It is readily soluble in a 1 per cent. solution of Na_2CO_3, and is incompletely precipitated from its solution by dilution, but completely by passing a stream of CO_2 through it. It has not as yet been obtained free from lecithin. It may be prepared from egg yolk by extraction with successive portions of ether as long as it yields any color to the solvent. The ether is evaporated, the residue is dissolved in the smallest possible amount of 8 to 10 per cent. NaCl solution. It is precipitated from this solution by an excess of water, and purified by the repetition of this process. The operation must be conducted as rapidly as possible, since the prolonged action of water renders the vitellin insoluble in NaCl solution. Thus obtained, it is still mixed with a small amount of lecithin.

Crystallin is usually regarded as identical with vitellin. It can be prepared in the pure form from the crystalline lens, in which it occurs to the extent of 24.6 per cent. In dilute saline solution it coagulates at 75° C.

Serum Globulin—Paraglobulin—Fibrinoplastin—occurs in blood, chyle, lymph, and serous fluids. In many of these fluids it exists in large quantity, and these coagulate spontaneously when removed from the living body, forming fibrin—probably by the combination of two modified forms of globulin, called fibrinogen and fibrinoplastin. Globulin is not completely precipitated by a saturated solution of NaCl, but is precipitated by alcohol, or by allowing carbon dioxide to bubble through the liquid.

Pure paraglobulin is insoluble in water. Its dilute saline solution coagulates on heating to 75° C. (167° F.). Globulins also occur pathologically in the urine, and may usually be discovered by dropping a few drops of the urine into a large quantity of distilled water, when the globulin precipitates as a white cloud.

Cell Globulin has been described as occuring in lymph corpuscles, and may be extracted from them by NaCl solutions.

Fibrinogen.—This globulin is found in blood plasma, together with paraglobulin and serum albumin. It is also found in chyle, lymph, serous fluids, transudations, and hydrocele fluid. During the clotting of blood it is converted largely, if not entirely, into fibrin. It resembles paraglobulin in its general properties, but is distinguished from it by the fact that in blood plasma, or a 1 per cent. solution of NaCl, it coagulates at 56° C. (132.8° F.), while paraglobulin coagulates at 75° C. (167° F.). It is also readily precipitated by the addition of 16 per cent. of NaCl to its solution, whereas paraglobulin is not precipitated until at least 20 per cent. is added.

It may be prepared from blood plasma which has been prevented from coagulating by the addition of $MgSO_4$. By the addition of an equal volume of a saturated solution of NaCl, the fibrinogen is precipitated, while the paraglobulin remains in solution. The characteristic properties of fibrinogen are, that in the presence of minute quantities of certain salts, of which NaCl and $CaSO_4$ are examples, the addition of fibrin-ferment causes a rich formation of fibrin. Without such addition, the solution of fibrinogen may remain permanent.

Myosin.—When an irritable contractile muscle passes into rigor mortis, the substance of which the muscle fibrillæ are composed undergoes a change similar to the clotting of the blood, which results in the formation of a clot of myosin. Myosin is the name given to a solid which separates on the coagulation of muscle plasma. Muscle plasma, freed from blood, is a yellowish, opalescent syrupy fluid, which filters with difficulty, and clots spontaneously at temperatures above 0° C. (32° F.). It may be diluted with solutions of varying strengths of several neutral salts, by which its clotting may be delayed, and the changes it undergoes may be studied. Muscle plasma contains a globulin, **myosinogen,** which is a generator of myosin, which resembles fibrinogen, and coagulates at 56° C. (132.8° F.). This is converted into myosin on clotting by the action of a specific ferment, and there remains in the solution, after the formation of the clot, myoglobulin and an albumin resembling serum albumin. Apart from these general reactions, myosin is distinguished by its low heat coagulation temperature, 56° C. (132.8° F.). It is converted into an insoluble proteid by the prolonged action of water, and into **syntonin** by the action of acids. Globulins closely resembling myosin occur in vegetable protoplasm, and in the cells of the liver. Myosin is readily digested by pepsin, more slowly by trypsin.

Globin is produced by the spontaneous decomposition of hæmoglobin on exposure to the air. It is an insoluble proteid of which little is known. It is scarcely soluble in dilute acids or alkalies, or in solutions of NaCl.

DERIVED ALBUMINS, OR ALBUMINATES.

There are two forms of these compounds, the **acid albumins** and **alkali-albumins.** They are obtained by dissolving albumin in acids or alkalies. Some of the acid-albumins contain sulphur, while the alkali-albumins do not. When freshly prepared, they are soluble in diluted acids, alkalies, and alkaline carbonates, and their solutions are precipitated by careful neutralization, but by boiling in neutral solutions only, and with difficulty by alcohol.

Globulins are more readily converted into acid albumins than the native albumins. Coagulated proteids, as fibrin, require acid in a concentrated form. As obtained from the various proteids, the products exhibit certain marked differences, indicating that each proteid yields its own special acid-albumin.

Preparation of Acid-albumin. — Blood serum, or the diluted white of egg, is digested at 40° to 50° C. (104° to 122° F.) for several hours with 1 per cent. to 2 per cent. of HCl. The solution is filtered, carefully neutralized, and the precipitate collected on a filter and washed with distilled water. It may be rapidly prepared by beating the white of egg with glacial acetic acid. A jelly is thus formed which can be dissolved in warm water, and from this solution the acid-albumin is precipitated by neutralizing and washing as before.

Syntonin is merely an acid-albumin which results from the action of acids on myosin, or muscle globulin. It has certain properties which distinguish it from the similar products of the action of acids on other proteids. For example: It is soluble in lime water; it is insoluble in acid sodium phosphate, NaH_2PO_4, while other acid albumins are soluble. When precipitated from its acid solution by neutralizing, the precipitate is more gelatinous than that of the other acid albumins, and is less readily soluble in alkalies.

Alkali-albumin may be obtained by the action of dilute alkalies on native albumin solutions, upon coagulated albumin or other proteids. The jelly produced by the action of KOH solution upon white of egg, is alkali-albumin. If serum, egg albumin, or muscle juice be treated with a dilute alkali, the proteid undergoes a change, and is converted into alkali-albumin. This solution is no longer coagulated by heat. The proteid is entirely precipitated upon neutralization, and the precipitate is insoluble in water and in neutral NaCl solutions, and is readily soluble in diluted acids or alkalies. It has been a matter of considerable discussion, whether acid-albumin and alkali-albumin, when precipitated by neutralization, are identical or different substances.

Casein or **Caseinogen** is a natural alkali-albumin found in the milk of mammals, and differs only in some slight particulars from that found in blood, muscle, etc. By some it is regarded as a nucleo-albumin.

Casein exists in milk in the soluble form, or in a state of semi-solubility. Under a high magnifying power, the casein can usually be seen as very fine granular particles, and therefore a portion of it, at least, must be in suspension, instead of in actual solution. There is a slight difference in the composition and properties of casein of cows' and of human milk, which explains a part of the difference in digestibility of the two. Casein is somewhat richer in nitrogen than alkali-albumin; it yields sulphur to heated potassium hydroxide, which alkali-albumin does not. It is coagulated by rennin, which is not the case with alkali-albumin. Its solutions do not coagulate on boiling, are precipitated by most acids, but not by simple neutralization in presence of an alkaline phosphate. Potassium ferro- and ferri-cyanides and dilute sulphuric acid precipitate casein in presence of free acetic acid. Rennet contains a special curdling ferment, rennin, as also do gastric and pancreatic juices, which can precipitate casein from alkaline solutions at slightly elevated temperatures.

This precipitation is due to the specific action of an enzyme, which results in the formation of a substance differing essentially from casein and called **tyrein.** It has been proposed to call the coagulated product **casein,** and the substance in solution **caseinogen.** The relation of these bodies is the same as that between fibrin and fibrinogen. Simultaneously with the formation of the clot, a by-product is formed having the properties of the soluble albumins. The curd differs from casein in the fact that it is less soluble in acids and alkalies; casein always leaves a larger amount of residue on ignition. Calcium phosphate seems to play an important part in the coagulation of casein. If the casein be freed from calcium phosphate, and dissolved in a dilute alkali, it will not yield a curd. It may be also stated that casein precipitated by acids instead of by rennin cannot be employed for the manufacture of cheese, as it will not "ripen." Cheese can only be made by the use of rennin. When milk is submitted to dialysis, to separate the inorganic salts, it yields no clot with rennin; but if the salts be added again, it yields a clot. The action of calcium phosphate appears to be, that it assists in the separation of the clot from the solution. The calcium salt is not alone essential for this, as similar salts of Mg, Ba, or Sr will give similar, though less efficient, results.

Solutions of alkali-albumin cannot be made to clot by the action of pure rennin.

The casein of cows' milk differs from that of human milk in the following particulars: 1. Human milk forms finer coagula than cows' milk, and sometimes not at all, with rennin. 2. In human milk the casein yields a very imperfect precipitation with acetic acid, which is a finely flocculent precipitate as compared with the coarsely flocculent precipitate yielded by cows' milk. The casein can be completely precipitated from human milk only by saturation with $MgSO_4$, and not with acetic acid. 3. Casein from human milk is less soluble in water than that of cows' milk. When digested with gastric juice, casein yields caseoses instead of albumoses, and coagulated proteids. Lehman says that cow casein is a double compound of casein-calcium with calcium phosphate, in which 1.4 to 1.7 per cent. of the calcium is combined directly with the casein. Cow casein contains about 7.2 per cent. of ash with 6.6 per cent. of Ca_3PO_4, while human casein contains but 3.2 per cent. of Ca_3PO_4.

It is thus probable that the two caseins are chemically different substances.

COAGULATED PROTEIDS.

Very little is known of the chemical characteristics of the proteids after coagulation. These products are produced by heating solutions of the proteids, generally in slightly acid solutions, or by the action of the various agents which have been mentioned above. They are insoluble in water, dilute acids, alkalies, and neutral saline solutions of all strengths. They are soluble only in strong acids or alkalies, though often the prolonged action of dilute acids or alkalies will effect some solution, especially at a high temperature. During these solutions, however, a destructive decomposition takes place, some acid- or alkali-albumin always being produced, together with some peptone and allied substances. The coagulated proteids are readily converted into peptones, at the temperature of the body, by the action of the gastric or the pancreatic juice. All proteids in solutions are precipitated by alcohol. If the alcohol be rapidly removed, the proteids are again soluble in water; but if the precipitate be left in contact with the alcohol for some time, it loses its solubility.

Fibrin is a white, elastic, more or less fibrillated solid, insoluble in water or dilute salt solution. It is soluble in acids (1 to 5 per cent.) with difficulty. With strong hydrochloric acid, it forms a violet solution. When boiled with caustic alkaline solutions, it forms ammonia and alkaline sulphides. Fibrin may be prepared by whipping blood with a bundle of twigs, and washing the coagulum with water and then with alcohol and ether.

It is doubtful whether fibrin is a single substance, or whether there are several. The solubilities and behavior of fibrins depend very much upon the conditions of their formation. When unboiled fibrin is washed until it is white, and digested by active trypsin, it is largely converted into coagulable proteids during the first stages of the digestion. These proteids are globulins, one of which is closely related to paraglobulin, as its saline solutions coagulate at 75° C. (167° F.). A second globulin, the product of trypsin digestion, coagulates at 55 to 56° C. (131 to 132.8° F.), and in this respect closely resembles fibrinogen. Globulins are also produced by the action of pepsin in the first stages of its action upon raw fibrin. If the fibrin is boiled, or treated for some time with alcohol before digestion with trypsin or pepsin, mere traces, if any, of these globulins are obtained. It is possible, therefore, that the globulins obtained by this treatment may be present in the raw fibrin, as such. When boiled with water, or treated for some time with alcohol, fibrin loses its elasticity; its solubility in the various reagents is lessened, and its digestion with pepsin and trypsin is rendered more difficult. It resembles the other coagulated proteids. Fibrin has the peculiar property of decomposing hydrogen peroxide. Pieces of fibrin placed in this fluid seem to undergo no change, but decompose the H_2O_2. Guaiacum is turned blue by fibrin in the presence of H_2O_2 or turpentine, and in this respect giving the reaction for blood with this reagent.

In comparing globulin, myosin, and fibrin, they form a series in which myosin is intermediate between the globulin and fibrin in its solubility and most of its reactions. Myosin is, in fact, a somewhat more soluble form of fibrin, depositing in clumps or masses instead of in threads or filaments.

ALBUMOSES OR PROTEOSES.

When any of the proteids above described are submitted to the digestive action of pepsin, trypsin, or certain other enzymes, certain intermediate products are produced in the earlier stages, which finally become peptones. When the digestive fluid employed is pepsin with dilute HCl (0.2 per cent. solution), a small portion of the proteid is first converted into acid-albumin. This may be precipitated by neutralizing such a fluid in the early stages of the digestion. At a later stage of the digestion, this acid-albumin disappears, and other products make their appearance which are known collectively under the name of albumoses, or proteoses. By the continued action of pepsin and hydrochloric acid, these albumoses are changed into peptones as a final product.

The process above described consists in a gradual hydrolysis of the proteid molecule with the result, at first, of a cleavage or splitting of the molecule into two groups of radicals, known as the hemi-group and anti-group. These groups give rise to two distinct classes of products. These two groups may be separated by the action of sulphuric acid (3 per cent.) at 100° C. (212° F.), about half of the proteid going into solution, there remaining (anti-group) a gelatinous mass, insoluble in dilute acids, but readily soluble in a dilute solution of sodium carbonate. It is only slightly digested by gastric juice, but is readily dissolved by pancreatic juice, and converted into anti-peptone. The above mentioned residue, insoluble in dilute acids, is now generally called **antialbumid,** but was formerly called hemiprotein. The sulphuric acid solution contains the decomposition products of the hemi-portion of the proteid molecule, viz.: hemialbumose, hemipeptone, leucin, tyrosin, etc. Hemipeptone is gradually changed by the trypsin of the pancreatic juice into simpler crystalline compounds like leucin, tyrosin, etc., while antipeptone is incapable of further change by trypsin. The action of pepsin-hydrochloric acid upon albumin can be summarized as follows: The first action is to form acid-albumin. This is then split into two groups of primary proteoses, called *proto-albumoses* and *hetero-albumoses*, of each of which there is a hemi- and an anti-variety. The first of these is produced principally from the hemi-groups of the albumin molecule, with a much smaller amount coming from the anti-groups. The second is produced principally from the anti-groups, a smaller quantity being furnished by the hemi-groups.

The primary proteoses are changed by further action of the pepsin into secondary proteoses or deutero-albumose, and finally into peptones, of which there are two varieties. The cleavage of the albumin molecule, under peptic digestion, also splits off a certain amount of *anti-albumid*, which is further changed into deutero-albumose and finally antipeptone.

The gastric digestion of proteids is thus seen to be a complicated process. The following scheme will make these changes somewhat clear.

ALBUMIN.

Acid Albumin.

(Hemi Group.)	(Anti Group.)	
Hemi-Proto-Albumose. Anti-**Proto-Albumose.**	**Anti-Hetero-Albumose.** Hemi-**Hetero-Albumose.**	**Anti-albumid.**
Hemi-Deutero Albumose. Anti-**Deutero-Albumose.**	**Anti-Deutero-Albumose.** Hemi **Deutero-Albumose.**	**Anti-Deutero-Albumose.**
Hemi-Peptone. Anti-**Peptone.**	**Anti-Peptone.** Hemi-**Peptone.**	**Anti-Peptone.**

NOTE.—The bold face type indicates that that variety of each product is formed in largest amount, while the prefixes hemi and anti indicate from which group or part of the molecule each is formed.

When trypsin is employed in the digestion of proteids, the process is somewhat different, and the decompositions of the proteid are much more complicated than is the case with pepsin. Instead of acid-albumin, a small quantity of alkali-albumin is at first formed, together with more or less coagulable globulin. Albumoses soon make their appearance, which are somewhat rapidly converted into peptones, some of which, in turn, are converted into leucin, tyrosin, and other products. Somewhat similar products of decomposition may be produced by the action of acids and alkalies alone upon proteids. The character of the products depends upon the concentration of the acid, the temperature and the duration of the action.

Proteids may also be peptonized by the action of water at a high temperature and under pressure. The albumoses are thus the true primary products of the hydrolysis of proteids.

The albumoses are best prepared by the action of a small amount of very active pepsin on a large amount of fibrin previously treated with 0.2 per cent HCl at 40° C. (104° F.), or by heating proteids with water under pressure for several hours at about 150° C. (302° F.). Under the action of pepsin the fibrin dissolves, and, as soon as this is complete, diluted Na_2CO_3 solution is added until the reaction is faintly alkaline, when the acid-albumin is precipitated. This is removed by filtration, and the filtrate contains albumose with but a faint trace of peptone. The primary albumoses (proto-albumose and hetero-albumose) may be precipitated from this solution by strongly acidifying with acetic acid and saturating the solution with NaCl. The albumose, as thus precipitated, may be collected on a filter and washed with a saturated solution of NaCl. It may again be dissolved in water if desired.

Solutions of albumoses give the following reactions:

First. Acetic or nitric acid, added drop by drop, precipitates primary albumoses in the cold, the precipitate dissolving on warming to separate again on cooling.

Second. If the solution be slightly acidulated with acetic acid, avoiding all excess, and a trace of potassium ferrocyanide be added, a precipitate forms which disappears on warming to reappear again on cooling.

Third. On adding caustic soda in excess and a drop of a copper sulphate solution, the biuret reaction is obtained. This reaction is also obtained with solutions of peptones, but not with other soluble proteids. (See Table, p. 497.)

Fourth. A weak solution of copper sulphate (2 per cent.) precipitates primary but not secondary albumoses.

Peptones.—The gastric, pancreatic, and probably the intestinal juices convert albuminous bodies into a more soluble and diffusible form, called **peptones.** Several different peptones have been described, but some of them are probably mixtures of albumoses and true peptone. Since the conversion is a gradual proprocess of hydration, it is but natural to expect such a mixture.

Dehydrating agents, as heat, can reverse the process, and convert peptone into albumin.

The reactions of peptones are mostly negative. Solutions of peptone do not exhibit a viscid character, are not coagulated by heat, nitric acid, or acetic acid and potassium ferrocyanide. Alcohol precipitates them, but the precipitate is soluble in water. Tannin, mercuric chloride, picric acid, and potassio-mercuric iodide precipitate them in the cold.

The most marked property is their extreme solubility in water and their comparatively ready diffusibility through animal membranes. Amyloid matter is not converted into peptone by pepsin or trypsin.

Peptones may be separated from albumoses by saturating the solution with ammonium sulphate, when the albumoses are precipitated, while the peptones are not. Nothwithstanding the formation of peptones in considerable quantities, during stomach and intestinal digestion, very little can be found in these localities at any time. They are probably absorbed as soon as formed. It is also a matter of interest, that they disappear as soon as absorbed, and are converted back into other proteids as soon as they enter the blood, or probably while passing through the membranes. It is believed that this change is produced by the tissue cells of the mucous membrane or of the villi.

THE COMPOUND PROTEIDS.

Besides the simple proteids which we have noticed, there are certain well-defined substances found in nature that are composed of compounds of these with some non-proteid body. In this class of substances we will include hæmoglobin and its derivatives, to be mentioned when we come to speak of the animal pigments. These are compounds of globulin with an iron containing pigment.

Mucin, another compound proteid, is a compound of a proteid with a carbohydrate, having a reducing power on Fehling's solution. They are sometimes called the **gluco-proteids.**

Mucin occurs in the cement substance of connective and epithelial tissues. It is also present in bile, and the secretions of mucous membranes.

To prepare it from bile precipitate with alcohol, dissolve the precipitate in lime water, precipitate again with acetic acid, filter, and wash with alcohol or ether. It swells up in a little water, and dissolves in a large quantity. Its solutions do not coagulate on heating, and it contains no sulphur. It is insoluble in alcohol, ether, chloroform, or gastric juice.

Its solutions are precipitated by acetic acid, alum, basic acetate (sub-acetate) of lead, and very dilute mineral acids. Its solutions dissolve oxide of copper, and thus hinder the copper test for sugar, when applied to urine containing an abundance of mucus.

Closely related to mucin are certain substances which form ropy solutions, but which are not precipitated by acetic acid. These have been named **mucoids** or **mucinoids.** They occur with mucin in submaxillary saliva, in intestinal mucus, in the umbilical cord, etc.

Another group of the compound proteids are compounds of a **proteid** with nucleinic acid. They are phosphorized bodies called **nucleins**. They are insoluble in water and in gastric juice, but are more or less soluble in alkalies.

Nuclein is the name given to the material of which the nuclei of cells are principally composed. When pus or yeast cells, or red blood-corpuscles, yolk of egg, or salmon eggs are extracted with water and diluted HCl, the cells are broken up and dissolved, and the nuclei separated from them. By treatment of the solution with alcohol and ether, and final digestion with pepsin, the nuclein is left as a residue. When prepared pure, it is an amorphous substance rich in phosphorus, which is set free as phosphoric acid when it is boiled with alkalies. At the same time a proteid is produced as one of the products of the decomposition. Nuclein has lately come into prominence as a therapeutic agent for the treatment of certain contagious and wasting diseases. **Nuclein** is a compound of **nucleinic acid** with a complex basic substance. This basic substance is different in nucleins from different sources, but the nucleinic acid seems to be the same in all. The basic substance yields, on decomposition with reageants, one or more of the xanthin bodies. When treated with oxidizing agents, nuclein gives uric acid, and is believed to be an antecedent of uric acid. The nucleins seem to be free from toxic properties, but have a marked microbicidal effect. They are used hypodermically, in the form of a 1 to 2 per cent. solution.

Nucleo-albumins.—These compounds are complex compounds consisting of a nuclein combined with a globulin. They are found together with nuclein in living cells, more especially of the glandular organs, such as the thymus, spleen, liver, kidney, etc.

Nucleo-albumin resembles mucin in physical properties, the solutions having the same viscid character, both being precipitated by dilute acetic acid. The viscid appearance of fresh bile is due to nucleo-albumin instead of mucin, as formerly supposed.

When nucleo-albumins are submitted to gastric digestion, the proteid portion of the molecule is converted into peptone, leaving insoluble nuclein. Caseinogen of cows' milk is now regarded as a nucleo-albumin by many chemists, for when submitted to gastric or pepsin digestion a residue of nuclein is always left undissolved.

Albuminoids or **Gelatinoids** (Collagens).—Under this head we shall include several groups of more or less insoluble bodies, resembling the true proteids in some particulars, but attacked by the digestive ferments with difficulty.

Most of these bodies when decomposed by dilute acids and heat yield leucin and tyrosin.

Collagen is the name given to the substance composing the white elastic tissue of the skin, tendons, etc. When boiled for some hours with water it forms gelatin. **Collagen** and **ossein** seem to be closely allied in both composition and properties. **Ossein** is the proteid basis of bones, and is converted into gelatin by boiling with water. Embryonic tissues when boiled, yield **mucin** and **chondrin** instead of gelatin.

Gelatin, in the pure state, is a colorless or slightly yellowish, transparent, vitreous, tasteless mass. It swells in cold water, and readily dissolves in hot water or glycerin, forming a thick, viscid solution, which sets or gelatinizes on cooling. Heating to 140° C. (284° F.), or long-continued boiling destroys this power of gelatinizing. It is soluble in dilute acetic and other acids, but insoluble in alcohol, ether, and the oils. Solutions of gelatin dissolve copper oxide with a blue color, which, on boiling, is reduced, but without separation of red oxide; it therefore interferes with the copper test for glucose. An impure gelatin prepared from animal refuse (bones, hides, etc.), when in the dry state, forms glue. **Liquid glue** is a solution of glue in acetic acid. Solutions of gelatin are precipitated by tannic acid, mercuric chloride, alcohol and chlorine water, but not by acetic acid and potassium ferrocyanide, alum, or acetate of lead. Gelatin is lævorotatory.

Chondrin exists in permanent cartilages, and forms gelatin on boiling with water. The gelatin from this source differs slightly from that prepared from collagen or ossein.

Elastin. — This is the characteristic component of elastic tissue, after the removal of gelatin, mucin, fats, etc. It is usually prepared from the ligamentum nuchæ of the ox, which is cut into fine slices, boiled for three or four days in water, and then for some hours with a 1 per cent. KOH solution, and finally with water. This is then repeated with 10 per cent. acetic acid, and finally it is treated 24 hours with cold 5 per cent. HCl, washed with water, boiled with 95 per cent. alcohol and extracted for at least two weeks with ether, to remove the fat. There is left a pale yellowish powder, in which the fragments of the original elastic tissue may be distinguished under the microscope. When moist it is yellow and elastic, but on drying becomes brittle. It may be digested with pepsin or trypsin, and is readily corroded and dissolved by papäin.

Keratin.—This is the chief constituent of hair, nails, feathers, horns, and epidermal structures in general. It is mixed, however, in these structures, with small quantities of proteids and other substances, from which it may be freed by thorough extraction with water, alcohol, ether, and dilute acids, followed by digestion with pepsin and trypsin. The composition of keratin is closely allied to that of the true proteids.

Neuro-kerotin is an allied substance found in brain tissue.

Chitin, $C_{15}H_{26}N_2O_{10}$, is not found as a constituent of any mammalian tissue, but is found in the exoskeleton of many invertebrates. It is more analogous to the cellulose of plants than to the proteids. The most convenient source is the shells of crabs and lobsters.

Spongin is the chief constituent of the sponge.

Fibroin, $C_{15}H_{23}N_5O_6$, is the chief constituent of silk, and is covered with a glue known as sericin, which is soluble in warm soap-water.

Lardacein, or **Amyloid Matter,** is an amorphous, friable mass, occurring in certain regions of the body as a pathological product. It seems to be a derivative of fibrin. It is generally found as little transparent grains, or corpuscles, somewhat resembling starch granules. The usual locations are the liver, spleen, and kidneys. It gives many of the proteid reactions. It is stained a reddish-brown color with iodine, which is changed to a violet or blue tint by diluted sulphuric acid. Anilin violet stains it rose-red or violet instead of blue. Eosin stains it a bright red color.

VEGETABLE PROTEIDS.

The amount of proteid matter in plants is less than in animals. They do not differ essentially in composition or properties from those found in animals. They occur in solution in plant juices, or as composing the protoplasm of the cells, or deposited in the form of granules (aleurone grains).

Plant proteids have received less attention than the proteids of animals. Representatives of each of the same five or six classes of proteids above mentioned are to be found.

Vegetable Albumins are sparingly found. Most of the proteid substance found dissolved in plant juices, and precipitated by boiling, is globulin and not albumin.

Plant globulin or **plant vitellin** is the most abundant proteid found in plants. This globulin, like animal vitellin, is insoluble in water, and soluble in a weak solution of NaCl. It coagulates at about 75° C. (167° F.). This substance, as it occurs in the aleurone grains of many plants, is distinctly crystalline. It is thus the purest native proteid known.

Plant Myosin and **Paraglobulin** have also been found.

Of the **vegetable albuminates** the two best known are **legumin,** or **vegetable casein,** and **conglutin** of almonds and lupines.

Legumin occurs in the leguminous plants as an alkali-albuminate. It may be obtained from softened peas or beans. It resembles casein in its properties. Some recent investigators claim that it does not occur as an alkali-albuminate in the plant, but as a globulin, which is changed into an albuminate by the method of extraction. Like all the globulins, it is easily soluble in alkalies and acids.

Proteoses or **Albumoses.**—Many plants contain proteids of this class. Martin has described four proteoses found in papaw juice, and two in wheat flour. In the papaw they are associated with the ferment papäin, and are probably produced by the action of this ferment upon the globulins of the plant. Papäin acts upon animal proteids in alkaline or weak acid solutions to convert them into proteoses and finally into peptones. It does not form peptone with vegetable proteids. Leucin and tyrosin are formed, however, in small amounts.

Peptones, for the above reason, rarely occur in plants.

Coagulated Proteids of vegetable origin are produced by heating the plant, when the albumins and globulins are coagulated. The fibrin-like body formed from wheat flour by treatment with water, and from which the starch may be washed with cold water, is a compound or mixture of two proteids found in the flour. The proteids in wheat compose about ten per cent. of the weight of the grain. The most recent investigations show that there are four different proteids present. An albumin existing in from 0.3 to 0.4 per cent. of the weight of the grain, a globulin in from 0.6 to 0.7 per cent., a proteose in about 0.3 per cent., gliadin existing in 4.25 per cent., and glutenin (gluten casein) in 4.5 per cent. of the grain. **Gluten fibrin** or **gluten** is principally made up of a mixture of the last two of these bodies. Gliadin is soluble in pure water, but in the presence of the salts of the flour, it forms a sticky, tenacious mass which adheres to the glutenin, which is insoluble, forming a tough, glutinous mass, inclosing starch to form a dough. By washing or kneading this dough with cold water, the starch may be washed out together with the other proteids, and gluten is left. Some investigators have claimed the presence of a ferment, while no one has ever isolated it, and some deny its presence or the necessity for it, in the formation of gluten. Gluten is soluble in weak alkalies and acids, and it forms peptones in gastric and pancreatic digestion.

Zein is a fibrin-like proteid found in maize with several other proteids. It is soluble in ordinary alcohol.

Leucosin is an albumin found in rye, wheat, barley, etc.

Edestin is the name that has been given to a globulin found in wheat, rye, barley, and other cereals.

Most of the cereal grains also contain a proteose, probably formed by ferment action, from the other proteids.

THE PRINCIPAL ANIMAL PIGMENTS.

BLOOD PIGMENTS.

The **hæmoglobins,** or blood pigments, form the chief constituent of red blood corpuscles in vertebrates, and occur in the muscle of mammals, and in the blood of a few of the invertebrates. They all crystallize, but not with equal facility. All hæmoglobins are of a blood-red or brick-red color when in powder. They contain from .4 to .6 per cent. of iron, and differ slightly in composition. They are compound proteids.

The crystalline forms of hæmoglobins vary in different animals. The crystalline blood pigments are oxyhæmoglobins Hæmogobin forms a feeble compound with oxygen which is released by heating its solutions in a vacuum, or in presence of ferrous sulphate, ammonium sulphide, stannous chloride, etc. Reduced hæmoglobin and oxyhæmoglobin are distinguished by their absorption spectra, the latter showing two such bands separated by a green band, while the former shows but one broad band occupying nearly the position occupied by the greenish-yellow band between the dark ones above mentioned. (See Figs. 10 and 11, Frontispiece.) Hæmoglobin unites with nitric oxide, carbon monoxide, hydrochloric acid, hydrocyanic acid, carbon dioxide, etc. Some of these compounds give peculiar spectra; these gases are not easily expelled by oxygen, and hence are deadly poisons when inhaled.

Hæmatin, $C_{34}H_{35}N_4FeO_5$, is obtained in the form of a salt, by the decomposition of oxyhæmoglobin with an acid. It is an amorphous, blue-black mass, with a metallic lustre, insoluble in water or alcohol, but soluble in alkalies. It yields two different spectra; one with oxygen, and another with carbon dioxide.

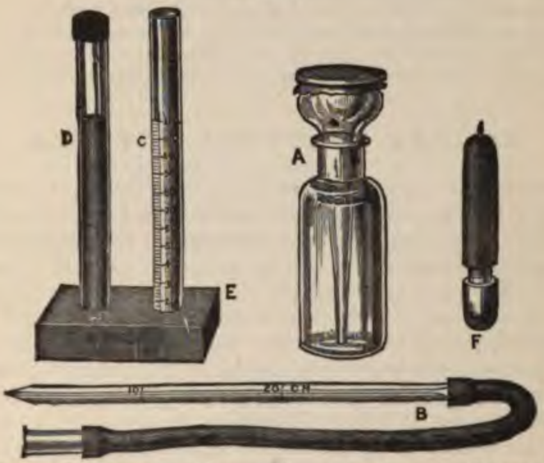
Hæmatin Hydrochlorate, or **hæmin** crystals, may be obtained by heating hæmoglobin, or dried blood, with common salt and glacial acetic acid. It forms thin, rhombic plates, having a brown-red color. The formation of these **blood crystals** is used to detect blood stains in criminal cases. The drop of dried blood is placed upon a microscopic slide, together with some pulverized common salt, and then treated with glacial acetic acid, and a cover glass placed upon it. The slide is heated until bubbles appear in the acid, cooled, and examined with a ¼ inch objective. The presence of blood is indicated by the presence of the crystals.

The amount of hæmoglobin in the blood is most easily determined, for clinical purposes, by the **hæmoglobinometer.** The process depends upon the imitation of the color of a standard solution of hæmoglobin, or colored glass plate, by dilution of a measured volume of blood until its color is that of the standard. The simplest and best for clinical purposes is that known as Gower's, represented by Fig. 62. It consists of two glass tubes of the same diameter. One (*D*) contains a standard of the tint of normal blood when 20 cubic mm. are diluted to 2 c.c. (1 in 100). It is filled with a glycerine jelly, colored with carmine and picro-carmine so as to get the right tint. The second tube (*C*) is so graduated that 100 divisions represent 2 c.c. The instrument is used as follows:

The finger is pricked, and the drop of blood that issues is drawn into the pipette shown in the figure, until it reaches the 20 mm. mark. It is then quickly blown out into the tube (*C*), into which a few drops of distilled water have previously been placed, and quickly shaken to prevent coagulation. Distilled water is then added until the tint of this mixture is exactly that of the standard in (*D*) when viewed by transmitted light.

Since average normal blood gives the tint of the standard when diluted to the 100 mark, the degree of dilution used to give that tint, in any given sample of blood, gives the per cent. of the normal amount of hæmoglobin in that blood. Thus, if the tint of the standard is reached when the sample is diluted to the 70 mark, the blood under examination contains 70 per cent. of the normal amount of hæmoglobin. To determine the quantity of hæmoglobin, it is only necessary to make the standard color by dissolving a known weight of hæmoglobin crystals in water, and comparing with the diluted blood as above. When the color in both tubes is alike, they contain the same amount of hæmoglobin.

FIG. 62.



GOWER'S HÆMOGLOBINOMETER. A, PIPETTE BOTTLE FOR DISTILLED WATER; B, CAPILLARY PIPETTE; C, GRADUATED TUBE; D, TUBE WITH STANDARD DILUTION; F LANCET FOR PRICKING THE FINGER

An exact quantitative estimation is seldom necessary for clinical purposes.

Methæmoglobin is a slightly changed derivative from oxyhæmoglobin, produced by the action of many reagents, as acids, alkalies, many salts, etc., or by simply exposing a solution of blood to the air for some time. It is characterized by an absorption band not found in fresh blood, and situated between C. and D. (See Frontispiece No. 14.)

Hæmocyanin is a globulin-like body found in solution in the blood of some invertebrates. It contains copper as one of its constituent elements, instead of the iron of hæmoglobin. It turns blue on exposure to the air, and such blood is blue when oxidized, and colorless when reduced.

Hæmochromogen is a pigment prepared from hæmoglobin by acids or alkalies, in entire absence of oxygen. The hæmoglobin is split into two compounds by the reagents, the one being a proteid, and the other the above coloring matter. It is very similar, though not identical, with hæmatin.

Hystohæmatin is the name that has been given to a class of pigments widely distributed in various tissues of both vertebrates and invertebrates. These pigments are regarded as the respiratory elements of the tissues, and play the same rôle there that hæmoglobin does in the blood. The best known of these pigments is **myohæmatin**. It occurs in muscles and probably other tissues, and is the medium of oxidation in these tissues.

Hæmatoporphyrin, Iron-free Hæmatin, $C_{68}H_{74}N_8O_{12}$ (?), is a pigment derived from hæmoglobin, by dissolving it in strong H_2SO_4, or by heating it with HCl. By diluting this solution with water, the coloring matter is thrown down, especially on neutralizing the acid. This pigment occasionally appears in the urine, as **urohæmatoporphyrin** or **urohæmatin.**

Hæmatoidin, $C_{16}H_{18}N_2O_3$, occurs as reddish, rhombohedral crystals in old blood clots, in corpora lutea and in the urine in cases of hæmaturia. It is believed to be identical with bilirubin, and shows the origin of bilirubin to be probably in the decomposed or disintegrated blood pigment, separated by the liver.

BILIARY COLORING MATTERS.

There are two pigments obtainable from bile and biliary calculi, viz.: **bilirubin** and **biliverdin. Bilifuscin, biliprasin, bilicyanin, choletelin, bilihumin,** and **hydrobilirubin** have also been described. The principal one of these, and probably the only one contained in bile when first secreted, is bilirubin, from which the others are derivatives.

Bilirubin, $C_{16}H_{18}N_2O_3$, is met with in the free state in the bile of man and the carnivora, and in ox bile; also, together with bilifuscin, $C_{16}H_{20}N_2O_4$, and biliprasin, $C_{16}H_{22}N_2O_6$, in combination with calcium, in biliary calculi.

It is now known to be identical with the red crystalline matter of old hemorrhagic clots, called **hematoidin,** and with **biliphäein, bilifulvin,** and **cholepyrrhin.**

It may be prepared by treating the powdered biliary calculus first with ether, then with boiling water slightly acidified with hydrochloric acid. The residue is washed with pure water, dissolved in hot chloroform, and filtered. The chloroform is distilled off from the filtrate, and the residue treated with absolute alcohol and ether, by which the bilifuscin is removed and bilirubin left. By dissolving this residue in chloroform and setting aside, a part of it may be obtained as a dark-red crystalline powder. It also exists in an orange-red, amorphous powder.

It acts the part of a weak acid, combining with sodium, calcium, barium, lead, etc. The formula of the calcium salt is $(C_{16}H_{17}N_2O_3)_2Ca$.

Bilirubin is closely related to hæmatin, a derivative of hæmoglobin. Moderately strong nitric acid, added to an ammoniacal solution of bilirubin, first colors it green, then blue (**bilicyanin**), violet-red, and finally yellow. (Gmelin's test for bile.) Nearly the same series of colors are produced by adding bromine to the chloroform solution, with the exception that it finally becomes colorless. Nascent hydrogen converts it into **hydrobilirubin**, $C_{32}H_{44}N_4O_7$ (**urobilin** of urine, **stercobilin** of fæces). Hydrobilirubin is a dark-brown amorphous powder, soluble in alkalies, sulphuric and acetic acids, alcohol, ether, and chloroform. It does not give the play of colors with nitric acid. It is probably formed in the fæces by the action of the nascent hydrogen set free by the butyric and putrefactive fermentations, upon bilirubin.

Biliverdin, $C_{16}H_{20}N_2O_5$ (or $C_{16}H_{18}N_2O_4$), is an oxidation product of bilirubin, and is readily formed by exposing alkaline solutions of this pigment to the air, or by similar treatment of fresh bile. It forms a green, amorphous powder, insoluble in water, ether, and chloroform. It is soluble in alcohol, acetic acid, and alkaline solutions, and reacts with nitric acid as does bilirubin. Hydrobilirubin may be prepared from it. **Biliprasin,** $C_{16}H_{22}N_2O_5$, is found in human gall-stones, and **bilifuscin,** $C_{16}H_{20}N_2O_4$, occurs in small quantities in old bile, and in gall-stones. According to Städeler, biliverdin is bilirubin + O and H_2O. Biliprasin is biliverdin + H_2O. Bilifuscin is bilirubin + H_2O. Viewed in this light, these various pigments would appear to be formed in the following order: Hæmoglobin, hæmatin or hæmatoidin, bilirubin, hydrobilirubin (urobilin), bilifuscin, biliverdin, and biliprasin.

Fuscin (retinal melanin) is found in the retinal epithelium. **Lipochrin** and **chromophanes** are found in the fat globules of the retinal epithelium. **Visual-purple** is also found in the retina of all vertebrates.

Pyocyanin gives the green or blue color to pus.

Urinary Pigments.—Besides urobilin, the urine contains at least one and possibly more, coloring matters. Uroxanthin or indigogen, is a normal constituent of urine, but is much increased in the first stage of cholera, and in carcinoma of the liver. According to some authors, this coloring matter is identical with **indican.**

Uroxanthin may be detected in urine by adding to the urine its own volume of hydrochloric acid, and a few drops of a solution of chloride of lime. The solution is colored red, violet, green, or blue, according to the amount of uroxanthin present. In some cases this test succeeds with hydrochloric acid alone.

In some cases, the urine containing uroxanthin on standing for some days becomes blue from spontaneous putrefaction.

Urobilin may be detected in fever urines by making them alkaline with ammonia, filtering and adding a few drops of zinc chloride solution, when it will show a green fluorescence. This urobilin reaction may be obtained more distinctly by shaking the urine with ether, separating the ethereal solution, and, after evaporating the ether, dissolving the pigment in absolute alcohol. This solution will usually show the green fluorescence. **Urochrome** (Thudichum), **uromelanin** (Thudichum), **uroërythrin,** and other pigments, have been described, but the whole subject is enveloped in much uncertainty and confusion.

Black urine is occasionally seen after breathing arseniuretted hydrogen, in carbolic acid poisoning, and after inunctions of tar.

Melanin (Melanogen) is the black pigment of the choroid, melanotic tumors, and skin of the negro.

Pathologically, it is found in the urine of persons suffering with melanotic cancer, and sometimes with malaria. It is sometimes deposited in the lungs. Urine containing melanin turns dark on exposure to the air, or, more rapidly, with oxidizing agents, as nitric or chromic acids. Its detection is useful to the physician, as an aid to the diagnosis of melanotic cancer of the liver, etc.

IMPORTANT VEGETABLE COLORING MATTERS.

Indigo is a blue coloring matter derived from several species of *Indigofera*, and other plants growing in India, Africa, and South America. It exists as a glucoside, called **indican,** which is extracted with water; the liquid, allowed to ferment in the air, deposits the indigo as a blue powder. Commercial indigo is a mixture of several bodies containing about 50 per cent. of indigo-blue or **indigotin,** $C_{16}H_{10}N_2O_2$. (See p. 468.) In dyeing with indigo, the goods are steeped in indigo-white, and then exposed to the air, when indigo-blue is deposited in the cloth. Indigotin has been prepared synthetically from toluene, C_7H_8, a homologue of benzene.

Litmus is a purplish-blue coloring matter obtained from lichens; generally from *Lecanora tartarea*, by steeping in urine, and adding lime and potassium carbonate. The mixture is exposed to the air for a few weeks, with frequent stirring, when a thick, blue solution is obtained. The solution is thickened up with plaster-of-Paris or chalk, formed into cakes, and cut into little cubes. The coloring matter of litmus is a weak acid forming salts having a blue color, the commercial product being the potassium salt. With acids, it becomes red from the liberation of the acid. **Turmeric** is the root of *Cucurma longa;* it yields a yellow tincture which turns brown with alkalies. The coloring principle is named curcumin, $C_{14}H_{14}O_4$. It is used to a large extent to give a yellow color to various articles of food, as mustard, chow-chow, vermicelli, etc.

Saffron is the stigmas of the flower of *Crocus sativa.* It yields to dilute alcohol a yellow coloring matter called **polychroit,** $C_{48}H_{60}O_{18}$, or a glucoside of **crocin,** $C_{16}H_{18}O_6$.

Tinctura croci is official. (U. S. P.).

Saffron is used to color certain articles of food, as butter, cheese, macaroni, etc.

Annatto is a yellow color obtained from the seeds of *Bixa orellana.* It is used in coloring butter, milk, cheese, etc.

Logwood, the wood of **Hematoxylon,** contains a purple dye, hematoxylin, $C_{16}H_{14}O_6.3H_2O$, used for purple and black dyes. It is official, and is used as a tonic and astringent. **Brazil wood** furnishes red dyes and lakes. **Cochineal,** the female of the insect *Coccus cacti,* yields to boiling water and alcohol a beautiful red coloring matter, which precipitated with alum and an alkaline carbonate yields carmine.

Chlorophyll is the name given to the green coloring matters of the leaves of plants. It occurs as microscopic granules distributed through the cell protoplasm in all the green portions of the plant. It may be extracted with alcohol, ether, and benzene.

Very little is known of this body, but it seems to be composed of two coloring matters, a blue and a green. It contains iron, and possesses the power, under the influence of sunlight, of decomposing CO_2 and uniting the carbon to the elements of water. The yellow color of autumn leaves is due to **xanthophyll,** an oxidation product of chlorophyll.

POISONS AND THEIR ANTIDOTES.

Of the emergencies which arise in every-day life, or even in the practice of the young physician, none are more embarrassing than acute poisoning. The word poison, to many people, carries with it an idea of horror and panic. The pharmacist is often consulted in haste, or may be called upon to render temporary aid until the services of a physician can be secured. He may in such cases render great service by administering the proper antidote, and thus saving valuable time. Even the physician is liable to something akin to alarm when he comes into the presence of a victim of a violent poison. It is for these reasons that we introduce a few of the most common poisons with their antidotes. We do not intend to give a guide to the treatment of cases of poisoning, but merely a few simple rules to be remembered as first aids to those suffering with acute poisoning.

The first thing to be considered is the **symptoms of poisoning**. Not unfrequently persons claim to have taken poison when such is not the case. Or, suspicious friends fear that poison has been taken. The author has often met with cases of this kind where a knowledge of the symptoms of poisoning has saved the patient a very disagreeable experience and the physician a great deal of trouble and future chagrin. The physician should be familiar with the nature and action of poisons, the symptoms which they produce, the circumstances which retard or otherwise modify their action, their chemical and physiological antidotes, the pathological changes they induce, and the methods of combating these results. It is our purpose here to name a few of the symptoms of poisoning, and then to offer a few hints as to antidotal treatment.

The chief characteristics of poisoning are, more or less severe symptoms coming on suddenly, or within a few hours after taking some substance or fluid into the stomach, the individual being previously in a state of health These symptoms usually increase steadily and uniformly, and tend to prove rapidly fatal. The symptoms may be greatly varied as to time and severity by the quantity or form in which the poison is administered, the state of the stomach—whether full or empty—the condition of the person—whether asleep or awake—and a certain idiosyncrasy of the individual. The symptoms which should arouse suspicion of acute poisoning are the sudden onset of pain in the region of the stomach of a healthy person, especially of a "burning pain," accompanied by dryness of, or a metallic taste in, the throat, more or less vomiting, great prostration of the vital powers, a deathly or cadaveric aspect, or an expression of great fear or concern, the rapid intervention of coma, and speedy death. If all, or the greater number of the above symptoms are present in any case, there is reason for suspicion, and the physician should govern himself accordingly. (See remarks under Arsenic, page 185.) Poisons may, for convenience, be divided into the following five classes, based upon their effects upon the human subject: 1st, Corrosives; 2d, Irritants; 3d, Neurotics; 4th, Septic Poisons; 5th, Gaseous Poisons.

Corrosive Poisons.—To this class belong those poisons which exert, principally, a local action upon the tissues with which they come in contact. The most important of this class are corrosive sublimate ($HgCl_2$), the concentrated mineral acids (sulphuric, hydrochloric, nitric), and oxalic acid; the alkalies and their carbonates (potassium, sodium, and ammonium hydroxides and carbonates); corrosive salts, as bisulphates of the alkaline metals, alum, nitrate of silver, chloride of zinc, butter of antimony ($SbCl_3$). Carbolic acid is a violent corrosive when concentrated, and also has a remote effect upon the system after being absorbed. The symptoms of corrosive poisoning follow immediately after taking the poison, and are a sense of acid, alkaline, or metallic, burning pain in the mouth, throat, gullet, and stomach, usually inducing vomiting, which, however, does not relieve the distress. The pain soon extends over the entire abdomen, and is accompanied with symptoms of shock, or collapse. There may be staining of the fauces or mouth.

Irritant Poisons.—Irritant poisons give rise to pain in the stomach of a burning character, usually coming on some minutes or hours after taking the poison. In this respect, they differ in their action from the corrosives. The pain is accompanied, or followed, by vomiting, faintness, purging, and tenesmus; the evacuations being often tinged with blood. The pulse is weak or irregular, and there is frequently severe headache. Death is usually caused by collapse, convulsions, or by inducing severe inflammations, which wear the patient out, after a variable period of time. Some have, also, a specific physiological action, besides their irritant action. The following are the more common irritants: Dilute mineral acids, concentrated organic acids, lime, zinc, copper, barium, silver, and mercuric salts; all compounds of arsenic and antimony; phosphorus, iodine, bromine, etc. Many kinds of food may, under certain conditions, become irritant poisons. Meat, fish, lobsters, tomatoes, etc., especially after having been canned and then exposed to the air. (See Ptomaines.)

Neurotic Poisons.—The neurotics exercise their action through the nervous system, and, therefore, only after absorption into the circulation. They rarely exert any local action. The neurotics are sometimes subdivided as follows:—

	Examples.
Narcotics, or those producing sleep,	Opium.
Anæsthetics, or those producing insensibility,	Chloroform.
Inebriants, or those producing intoxication,	Alcohol.
Deliriants, or those producing delirium,	Hyoscyamus.
Convulsives, or those producing spasms,	Strychnine.
Hyposthenisants, or those producing death by syncope,	Prussic acid.
Depressants, or those producing marked depression,	Nicotine.

Septic Poisons.—To this class belong certain poisons introduced into the body through abrasions of the skin, open wounds, or by the fangs or sting of venomous animals or insects. In many respects these poisons resemble, in their action, the depressing narcotics.

Poisonous Gases.—To this class belong carbon monoxide (charcoal fumes), carbon dioxide (choke damp), marsh gas (fire damp), illuminating gas, hydrocarbon vapors, sewer gas, confined air of living apartments, and noxious gases and vapors from manufacturing establishments.

TREATMENT OF ACUTE POISONING.

In every case of acute poisoning, or where the symptoms and circumstances indicate that a poison has been taken, the following is the course to pursue:—

1. Get the poison out of the system as soon as you can, unless it be a caustic.
2. Neutralize what you cannot remove.
3. Favor the natural elimination of the poison.
4. Combat any dangerous symptoms as they arise.

The first of these steps may be secured in one of three ways; viz.: by the use of **emetics** or the **stomach pump** or the **stomach tube.** If a stomach pump is not at hand, or in case corrosives have been swallowed and there is danger of doing damage in inserting it, the stomach tube may be introduced through the mouth or even through the nose. By attaching a funnel to the upper end of this, tepid water may be run into the stomach. On now turning the person upon his face or lowering the end of the tube, it acts as a siphon to run the water out. Repeat this process several times as in the process of **lavage** or until you are sure all poison is removed from the stomach. In the absence of a funnel, make as a substitute a cup-shaped cavity about the upper end of the tube with wax, putty, or even wet clay. The proper antidote or an emetic may be dissolved in the water used.

THE PRINCIPAL EMETICS.

Zinc Sulphate.—Give 20 grains at once, or dissolve ʒss in two ounces of water, and give a tablespoonful every 15 minutes.

Copper Sulphate.—Give 5 grains every 15 minutes, or, still better, 10 grains at once, followed by tepid water.

Alum.—A tablespoonfnl, given in syrup or honey.

Mustard (ground).—A dessertspoonful, stirred in tepid water and quickly swallowed. Very efficient, and is somewhat stimulating.

Apomorphine.—Give $\frac{1}{16}$ grain hypodermically.

Spr. Ipecacuanhæ.—Used mostly for children. Is depressing. fʒj every 15 minutes to a child two years old, until emesis is produced.

Tepid Water.—Drink copiously and until emesis occurs. It may be assisted by tickling the throat with a feather or the extended finger.

Common Salt.—A tablespoonful in a pint of lukewarm water is often effectual.

SPECIAL POISONS AND THEIR ANTIDOTES.

THE CORROSIVE POISONS.

Strong Mineral Acids.—Sulphuric, hydrochloric, nitric. *Symptoms.*—Staining of mouth or throat; immediate pain; vomiting; great prostration.

Antidotes.—Chalk, lime water, whitewash, magnesia, plaster from the wall, baking-soda, soap. Then give oil freely, and mucilaginous drinks. **Do not give emetics or use stomach-pump. All antidotes must be well diluted before they are given.**

Corrosive Vegetable Acids.—Oxalic, tartaric, acetic. *Symptoms.*—Burning pain, constriction in throat, and usually vomiting. Extremities cold; countenance livid.

Antidotes.—Same as for mineral acids except in the case of oxalic acid. When this acid is suspected to have been taken, use lime water or chalk only. Then give mucilaginous drinks, and stimulants.

Carbolic Acid (Phenol) **and Creosote.**—*Symptoms.*—Pain in stomach and whitened stains; odor; contracted pupils; coma; death by collapse.

Treatment.—Oils, then emetics or stomach-tube, unless the quantity taken was large and in the pure state. Sodium sulphate, in solution, has been recommended. A mixture of olive and castor oils with magnesia in suspension. Albumin of eggs given freely. Treat the collapse by injecting stimulants.

Caustic and Carbonated Alkalies.—*Symptoms.*—Acrid, burning taste in mouth, throat, œsophagus, and stomach; hoarseness; dyspnœa; vomiting of blood and mucus; surface clammy; pulse rapid; pain over abdomen, and diarrhœa.

Treatment.—Well-diluted vegetable acids, such as vinegar, lemon juice, tartaric or citric acids; fixed oils, such as castor, linseed, olive, or cod-liver oil. Mucilaginous drinks may be given freely. Do not give emetics or use stomach-pump.

IRRITANTS.

For general symptoms, see page 522.

Antimony—Tartar Emetic—Wine of Antimony or Oxide of Antimony.—*Symptoms.*—Metallic taste; nausea; violent vomiting; burning heat and pain in the stomach; purging; cramps, cold perspiration, and great debility.

Treatment.—Assist the vomiting by draughts of warm water, or mucilaginous drinks, such as flaxseed tea. Then give a cup of strong tea, or an infusion of oak bark, or a solution of tannin. This may be followed by opiates and stimulants.

Chloride of Antimony—Butter of Antimony.—*Symptoms.*—Same as above, but more caustic.

Antidotes.—Magnesia, with milk and water, baking-soda, tannin, as above, for tartar emetic.

Potassium Bichromate.—*Symptoms.*—Violent purging; painful vomiting of yellow vomit; dilated pupils; cramps in the legs; great depression.

Treatment.—Free use of lime-water, or magnesia in milk.

Arsenic—White Arsenic—Arsenous Acid.—*Symptoms.*—Come generally within a half hour, but may be delayed two or three hours. Faintness; nausea; constant vomiting; burning pain in the stomach, increased by pressure, and soon extends over abdomen; headache (frontal); diarrhœa; great thirst; catching, painful respiration; quick, feeble pulse; cold extremities, and anxious countenance. Death by collapse within twenty-four hours.

Treatment.—Expel the poison by thorough emesis. Promote the sickness by free use of albuminous or mucilaginous drinks. As an antidote, give raw eggs, beaten up in milk; freshly precipitated ferric hydrate or ferric hydrate with magnesia. The first is made by mixing together 100 c. c. of **liquor ferri tersulphatis** (U. S. P.), diluted with 1000 c. c. of cold water and 110 c. c. of **ammonia water** diluted with 250 c. c. of water. Let settle and wash it by decantation, filter through muslin, and shake the precipitate up with 250 c. c. (1 tumblerful) of water.

Ferric hydrate with Magnesia is prepared by shaking up 10 grms. of calcined magnesia in a quart bottle with about 800 c. c. of water until a smooth mixture is obtained; add 50 c.c. of solution of ferric sulphate, U. S. P., and shake again until a uniform smooth mixture is obtained, when it is ready for use. Solution of dialyzed iron has been used with success. These should be followed by stimulants well diluted.

Metallic Salts—Alum.—Alkaline bicarbonates, baking-soda.

Soluble Barium Salts.—Soluble sulphates, Epsom or Glauber's salt. Then give emetics.

EMETIC POISONS.

Soluble Copper Salts.—Albumin, white of egg and milk, baking-soda, followed by an emetic.

Iron—Green Vitriol—Persulphate of Iron.—Baking-soda and emetics or stomach tube.

Lead—Sugar of Lead, White Lead.—Solution of Epsom or Glauber's salt given with raw eggs. Then give emetics followed by castor oil.

Mercury—Corrosive Sublimate.—Albumin, white of egg, flour and milk, followed by emetics or stomach-pump, unless the poison was taken in a concentrated form. Then do not use the pump.

Silver Nitrate—Lunar Caustic.—Common salt, then emetics.

Zinc Chloride—Soldering Fluid, Burnett's Fluid.—Baking soda milk, white of egg, tea, decoction of oak-bark. Give opium to relieve the pain, then emetics if necessary.

Tin, Chloride of.—Baking soda, magnesia, milk and white of egg.

Iodine.—Most common from the tincture.—Give boiled starch paste, made thin enough to drink. In urgent cases use starch or flour, with cold water. Produce vomiting or use the stomach tube.

Phosphorus—Rat Poison.—Has no true chemical antidote. Magnesia, milk of magnesia, chalk, or lime suspended in gruel; turpentine. Give no fixed oils. Produce vomiting or use the stomach tube or pump.

Poisonous Meat, Fish, Lobsters, Etc.—*Symptoms.*—Nausea and vomiting 3 to 4 hours after taking food, gastro-intestinal irritation, great depression, scarlet rash at times, convulsions in young subjects, pupils either dilated or contracted. Recovery usual.

Treatment.—Encourage vomiting by copious draughts of warm water; counteract depression with diluted brandy or whiskey; relieve pain with opium or one of its preparations. Apply hot fomentations to the abdomen. When vomiting ceases, give castor-oil or other laxatives.

NEUROTICS.

Narcotics—Opium, Morphine, Laudanum, Paregoric, Soothing Syrups, Quieting Cordials, Etc.—*Symptoms.*—Appear in 20 to 30 minutes. Commence with giddiness, drowsiness, stupor, insensibility, with slow and stertorous breathing, weak pulse, contracted pupils, not reacting with light, surface sometimes cold, sometimes bathed in sweat; countenance livid. There is occasionally vomiting or convulsions preceding death.

Treatment.—First empty the stomach of any poison still remaining unabsorbed, by emetics or the stomach pump or tube. The patient is to be kept awake by forced walking, by the cold douche, or flagellations with wet towels. Faradic electricity may be applied to the spine. Give strong coffee in abundance. Atropine hypodermically, in $\frac{1}{100}$ grain doses, repeated until the pupils show its effects.

Anæsthetics—Vapors of Chloroform or Ether, Chloral, Methylene Dichloride, Nitrous Oxide, Etc.—Pure air, cold douches, artificial respiration, hypodermic injections of brandy, aqua ammoniæ (diluted), nitrite of amyl or nitro-glycerin. Galvanism or Faradism may be employed, if the instruments are at hand, but are of doubtful benefit.

Inebriants—Alcohol, Cocculus Indicus, Nitrobenzene (Essence of Mirbane), **Anilin, Etc.**—Emetics or stomach-pump, when there is reason to believe that any poison remains unabsorbed, then ammonium carbonate, hydroxide or acetate well diluted. Treat the narcosis as under opium.

Hyposthenisants or **Syncopants—Prussic Acid** (**hydrocyanic acid**), **Potassium Cyanide, Laurel Water,**

Peach Pits, Cherry Pits, Plum Pits, Etc.—No chemical antidote. Emetics or stomach-pump, where there is time. Cold effusions to face and neck, inhalations of ammonia; spirits of ammonia or nitroglycerin should be given internally with brandy.

Aconite (Monkshood, Wolfsbane, Blue Rocket).—*Symptoms.*—Heat, numbness and tingling in the mouth and throat, giddiness, loss of muscular power, sometimes delirium or purging. The skin is cold, the pulse extremely feeble, breathing oppressed. Death by collapse or asphyxia.

Treatment must not be delayed. Emetics or stomach-pump, Give castor oil, animal charcoal, or strong coffee. Stimulants will be needed—brandy, ammonia, nitrite of amyl, nitroglycerin Artificial respiration if necessary.

DELIRIANTS.

Belladonna (Deadly Nightshade).—*Symptoms.*—Dryness of fauces, thirst, flushing of face, dilatation of the pupil, double vision, giddiness, indistinct vision, delirium and stupor, or occasionally convulsions. Symptoms appear in a half hour after dose.

Treatment.—Stimulants, emetics; morphine acts well in some cases.

Stramonium (Thorn-apple, Jamestown weed).—Fruit and leaves are poisonous. *Symptoms.*—Same as belladonna.

Treatment.—As in belladonna.

Hyoscyamus Niger (Henbane).—*Symptoms.*—Giddiness, excitement, sense of weight in the head, drunkenness, delirium, dilated pupils, double vision, ending in coma.

Treatment.—Stomach-pump, emetics ($ZnSO_4$), stimulants and full doses of castor oil.

NEUROTICS PRODUCING CONVULSIONS.

Nux Vomica, Brucine and Strychnine.—*Symptoms.*—Intense bitter taste, followed in a few minutes by difficult breathing, stiffness in neck, muscular twitchings, quivering of frame. The head is drawn back, the body arched backward. The face becomes dusky and drawn. Soon there are distinct spasms and great fear of death.

Treatment.—Emetics or stomach-pump before spasms, then tannin, tea, oak-bark tea. Keep the patient warm and quiet. Chloroform or chloral to control the spasms.

DEPRESSANTS.

Digitalis (Purple Foxglove), **Tobacco**, **Lobelia**, **Colchicum** (Meadow Saffron), **White Hellebore**. *Symptoms.*—Those of great depression, vomiting, irregular heart action.

Treatment.—Stimulants, emetics (mustard) and purgatives. Use stimulants freely. Wash out the stomach if seen in time, or give a mustard emetic.

Bites.—First wash thoroughly, then paint with carbolic acid (¼ strength) or tincture of iodine. Tie a handkerchief tightly above wound, until the above applications or strong nitric acid can be applied. Give alcohol freely in bites of snake, scorpion, tarantula, etc.

Stings.—Extract "stinger" if left behind. Apply mud, or a paste made of baking soda, or wash with weak ammonia water.

Poisoned Wounds,
Dissecting Wounds,
Infectious Diseases,
} Apply carbolic acid (¼ strength), or paint the wound and around it with tincture of iodine. Give stimulants internally.

Poisonous Gases—Sulphuretted Hydrogen, Chlorine, Bromine, Carbon Monoxide and Dioxide, Nitrous Fumes, Illuminating Gas, Sulphurous Oxide, etc.—See special gases in text.

Treatment.—Fresh air, rest, and mild stimulation. Artificial respiration when necessary.

IMCOMPATIBLES.

Substances are said to be chemically incompatible when, on being mixed together, they react upon each other so as to cause an entire change in the properties of the substances so mixed. They may cause the evolution of a gas, an explosive mixture or compound, a poisonous or very active substance formed from comparatively inert ones, or, a precipitation of one or the other of the ingredients in the new compounds formed.

Sometimes two or more substances are brought together with the intent of producing a new substance different from ether; as, $2KI + HgCl_2 = HgI_2 + 2KCl$. This can hardly be regarded as an incompatible mixture.

Of physiological and therapeutical incompatibility we shall have nothing to say here. The student will find the following rules of value to him in the beginning:—

1. A free acid is incompatible with the alkaloids and the metallic hydroxides and carbonates. The three mineral acids displace the organic acids from their salts. The converse of these statements is also true; *i. e.*, metallic hydroxides and carbonates are incompatible with the acids.

2. If two substances, when mixed, can form an insoluble third body, or can react so as to generate a gas, they are incompatible.

A knowledge of the solubility of the ordinary salts is, therefore, of great

importance to the physician. For example, lead or barium cannot exist in a solution with a sulphate; silver, lead, or mercurous mercury cannot exist in a solution with a chloride.

Substances are, therefore, incompatible with their tests and antidotes.

3. The alkaline hydroxides and carbonates are incompatible with the salts of the alkaloids and most salts of the heavy metals.

4. Iodides and bromides precipitate most of the heavy metals, and are therefore incompatible with them.

5. The vegetable astringents and bitters owe their properties largely to their gallic acid and tannin. Tannin and most vegetable astringents precipitate the heavy metals from their salts, and are therefore incompatible with them.

6. Powerful oxidizing agents (strong nitric acid, potassium permanganate, hydrogen peroxide, chlorine, the hypochlorites, potassium chlorate, etc.) should not be mixed with easily ozidizable organic substances, for fear of forming explosive compounds.

7. The two principal solvents of the U. S. P. are alcohol and water. Each of these has its own class of easily soluble bodies. These bodies are often precipitated from their solutions in either of these solvents by the addition of the other. Thus the tincture of iodine, camphor, essential oils, the gums and gum-resins, aloes, etc., are precipitated or rendered unsightly by the addition of water or watery solutions of drugs or chemicals.

8. There are some solutions that should always be prescribed alone, or in a plain watery solution, as they readily decompose. Among these may be mentioned the compound syrup of hypophosphites, Fowler's, Donovan's, and Lugol's solutions.

These few rules will serve to call the student's attention to the subject, and to the general range of incompatibles.

PART V.

PHYSIOLOGICAL AND CLINICAL CHEMISTRY.

Origin of Vegetable Energy.—In the consideration of living bodies we are led in the outset to divide them into two distinct classes; **plants** which grow silently under the action of sunlight, and **animals** which grow also, but manifest their impressions and their will by active movements. This difference is not, however, well marked in all cases, as plants are known to exhibit active movements.

The difference between plants and animals is more clearly defined by the character of their food, and the chemical processes which accompany their growth.

The vegetable receives its energy principally from the sun's rays, and feeds upon substances from the mineral kingdom, which are destitute of potential energy. With these substances, CO_2,N and H_2O, it undertakes to build up an organism.

In order to do so the absorption of the energy of heat and light is necessary.

These it obtains from the sun, or from some artificial source of light and heat which can take its place. By the aid of these, it chemically combines inert bodies into potential organic substances.

Animals, on the other hand, decompose and render sensible the potential energy stored up in organic substances prepared by the plant. This energy they convert into kinetic energy (heat, nervous energy, and muscular movement). At the same time, they eject the used-up products in the chemically inert form of CO_2, H_2O and urea, suited for the use of the plant.

In a word, **the animal lives on the energy stored up by the plant.** When an animal respires, it absorbs a quantity of oxygen, which varies from 9 to 300 thousandths of its weight in every 24 hours. Almost all of this oxygen is used to produce CO_2 and H_2O with its combustible matters. This is the principal source of its energy. Plant cells respire also in the same way and for the same purpose as animal cells. Plants use up a part of their stored energy in exactly the same manner as do animals, by oxidation.

The functions of the protoplasm in plants require the expenditure of energy, and this energy is produced by the oxidation of combustibles. In the plant then, we have two processes going on at the same time; the taking in of CO_2 and H_2O, and the construction of complex organic compounds from them, and the burning up of a portion of these compounds to furnish the necessary vital energy to carry on its functions, with the exhalation of of CO_2 and H_2O. The balance, however, is in favor of the first of these processes, during the daytime, but at night the plant lives like an animal, borrowing its energy from the combustion of its reserves. This fact is shown by the increase of temperature of certain plants at night, and of flowers just at the moment of expanding, or in the heat developed by the sprouting of grain, when the only source of energy is the decomposition of reserves.

Chlorophyll.—When the green parts of a plant are exposed to air and sunlight, they have the power in some way of absorbing the small amount of CO_2 from the air, and returning oxygen to the air. If we examine the plant for the carbon, we find a series of bodies which have been studied under the name of carbohydrates, viz.: glucose, lævulose, sucrose, starch, etc.

The first of these substances formed, so far as we can learn, are glucose and starch.

We also find that certain nitrogenous products are formed. The nitrogen used is usually in the fully saturated or chemically inert form; *i. e.*, ammonia, nitrates and possibly urea and amids or amins found in the soil. It is probable that most of these amid bodies are converted into nitrates before being used by the plant.

The mechanism that causes the decomposition of water and carbon dioxide has been proven to be the green coloring matter of the leaves.

It can be proven that this coloring matter, or **chlorophyll,** will produce the change when exhausted from the leaf with alcohol or petroleum either. The rapidity of the absorption of CO_2 and the evolution of O, is proportional to the intensity of the light.

The light from an incandescent electric light, or a strong gas light, will also cause the change.

The reaction between CO_2 and H_2O that takes place, by which

CO_2 dissappears and oxygen is evolved, would be represented as follows :—

$$\underset{\text{1 volume.}}{CO_2} \quad + \quad H_2O \quad = \quad \underset{\text{1 volume.}}{O_2} \quad + \quad \underset{\text{Formaldehyde.}}{\mathrm{C}\begin{smallmatrix}\equiv\mathrm{O}\,\mathrm{H}\\ -\mathrm{H}\end{smallmatrix}}$$

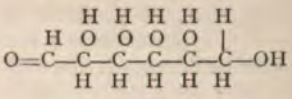
There are reasons for thinking that this reaction does not exatly represent the change that takes place, but that the chlorophyll, under the action of the sun's rays, combines with hydrogen to form a hydride.

The hydrogen is obtained by the decomposition of H_2O and the liberation of oxygen.

This hydride of chlorophyll, or **chlorophyllin**, gives up its hydrogen to the CO_2 as follows:

$$H_2 + CO_2 = COH_2 + O.$$

In either case the first compound formed is formaldehyde, which by polymerizing forms $C_6H_{12}O_6$ or—



$$\begin{array}{ccccccccccccc} & & & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} \\ & & \mathrm{H} & & \mathrm{O} & & \mathrm{O} & & \mathrm{O} & & \mathrm{O} & & | \\ \mathrm{O} & = & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C}-\mathrm{OH} \\ & & & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} \end{array}$$

It is thus that the plant prepares sugars, starch and cellulose, by the polymerization of formaldehyde, and then slight changes in the hydration or dehydration of the product.

The organic products of plant synthesis can be grouped into the following five classes :—

1. Alcohols, the sugars, and other carbohydrates.
2. Fats.
3. Hydrocarbons.
4. Albuminoid matters.
5. Nitrogenous substances not albuminoid.

Assimilation of Nitrogen.—It has been proven by many series of experiments that plants cannot, to an appreciable extent, assimilate free nitrogen from the air.

The present state of our knowledge teaches us that plants receive the most of their nitrogen as nitrates and ammonia. By far the largest absorption is as nitrates. These nitrates are produced in the air by electric discharges and the evaporation of saline waters. (See page 165.) A considerable production of nitrates takes place in arable soils under the influence of specific organisms which act upon ammonia and nitrogenous matters found in such soils. This organism is known as the **nitrifying**

ferment, and is always present in soils containing vegetable matter. (See page 552.)

It is probable that plants can absorb urea and some other suluble nitrogenous bodies of animal origin to a slight degree, but they are quickly transformed in the cells of the roots.

As we are not acquainted with the constitution of albuminoids, we cannot follow the reactions for the building up of these bodies in the plant. We do know by experience that plants thrive best on nitrogen in the form of nitrates; that the nitrates enter the circulation and reach the leaves, where they meet with very strong reducing agents in formaldehyde and glucose. This reduction probably takes place as we see it in the warming of alcohol with nitric acid, with the production of hydrocyanic acid, formic acid, and water. This reaction takes place at about 35° to 40° C., *i. e.*, at summer temperature.

We may represent the reaction as it would occur in the leaf as follows:

$$\underset{\text{Nitric acid.}}{2HNO_3} + \underset{\text{Formaldehyde.}}{5COH_2} = \underset{\text{Hydrocyanic acid.}}{2HCN} + 3CO_2 + 5H_2O.$$

The presence of hydrocyanic acid is well known in the almond, laurel, rose, peach, and many other leaves, fruits and flowers.

Again, it has been shown that hydrocyanic acid, in presence of water and formaldehyde, can form certain amids which have been recognized as among the decomposition products of albumin. It is probable then that the origin of albuminoid bodies in plants is that here indicated in brief outline, and represented by the following empirical reaction:

$$66CH_2O + 17CNH = \underset{\text{Albumin.}}{C_{62}H_{103}N_{17}O_{22}} + \underset{\text{Formic acid.}}{21HCOOH} + 2H_2O.$$

The albumin once formed, it can be transformed into other proteids In a brief way, then, we have traced a few of the synthetic reactions by which plants prepare their reserves of potential organic bodies, or bodies that on oxidation in the animal body, when used as food, can give out heat, nervous and muscular energy.

We have thus the source of the energy of animal life; for animals subsist upon the products prepared by plants, either directly, or subsist upon animals which in turn feed upon the stores of starch, gum, sugar, and albuminoid bodies laid up by plants. It will be noticed that the edible parts of plants are the fruits, tubers or root-stalks in which the plant has stored these reserves intended for the nourishment of the new germ, when needed to start it in its growth.

Animal Synthesis.—We have seen that the general result of plant growth is synthetical, while that of the animal is, in the main, destructive or analytical. In the animal, however, we have synthetic processes, which resemble those of the plant. There are a few animals whose cells possess chlorophyll (*Hydra viridis*). They behave like plants in the sunlight, giving off oxygen and storing up carbon. The formation of fat in the animal body out of albuminoids and carbohydrates is undoubtedly a synthetic process. Animals find it necessary to store up reserve products and they first convert a part of the potential energy into kinetic energy, and then reconvert it back into potential energy, stored up in the form of adipose tissue. When the food taken furnishes more energy than is required for present needs, the excess is partly stored up in the form of fat, to be liberated for use when the supply is deficient.

Proximate Principles.—When animals take food composed of the carbohydrates, fats, and albuminoids, they first get them into a soluble and diffusible form, then absorb them into their circulation. Then there begins a process of assimilation or appropriation.

The animal foods usually consist largely of albuminoid, fatty, and mineral matters, except in case of milk, which contains all of the classes above mentioned, or it is what has been called a perfect food. Although we take as food various mixtures of vegetable and animal tissues and products, we may divide the **proximate principles** into **carbohydrates** (including alcohols, starch, sugars, and gums), **fats, albuminoids** or **proteids,** and mineral salts. Each of these has its special uses in the economy, and all of them are necessary to the perfect maintenance of health. If either of them is lacking in our food, the body can, for a time, overcome the deficiency by transforming the others into a substitute of that which is missing. It is found, however, that this is always attended with loss of energy and well-being.

Origin and Role of Inorganic Substances in the Human Body.—Besides the organic matters of which we have briefly traced the origin, there exist in human tissues certain inorganic or mineral matters, which, from their constant presence, must have an important office to perform. The human body, as a whole, contains about 70 per cent. of water and 30 per cent. of solid matters. The amount of ash left on burning an adult body is from 3 to 5 per cent. There is, therefore, about a fourth of the body made up of dry organic matter.

Gaseous Matters.—Oxygen, partly combined and partly in solution, is found in the blood and almost all the liquids of the body. It unites in the blood with the hæmo-globin of the red blood cells, which renders it active and carries it to all the tissues.

In this manner it is brought in contact with the oxidizable products of the hydration of proteids, and burns them, and assists all the tissues in disposing of waste products of cell action. An adult absorbs from 770 to 850 grams of oxygen daily, and exhales by the lungs 540 to 720 grams as CO_2; a part of the remainder is exhaled by the skin in the same state, and a part is converted into water, urea, and other oxidation products.

The oxygen excreted is about one-fifth more than we inhale; the excess coming from the food taken.

Nitrogen is found dissolved in the blood and other fluids, and is contained in all cavities which are filled with gas. In combination it assists very largely in making up the tissues.

Carbon Dioxide is met with in expired air, and dissolved in many of the fluids of the body, and in the gases of the intestine. In the blood, saliva, lymph, bile and other fluids, it is found in combination as carbonates of the alkaline and earthy metals.

In the blood it is also found combined with the alkaline phosphates. One molecule of sodium phosphate, which alkalinizes the blood, combines with $2CO_2$. This weak compound can be decomposed and the CO_2 expelled, by passing through the fluid an inert gas at 37° C. (98.5° F.), or by the presence of oxygen combined with hæmoglobin.

It also forms weak combinations with serin and globulin of the blood. When diluted with water and heated, or when put in a nearly complete vacuum, these compounds part with the carbon dioxid. The CO_2 is carried from the tissues to the lungs in these weak combinations.

Hydrogen is found free in the gases of the intestines, where it is liberated by fermentation.

Water forms about 70 per cent. of an adult human body. The proportion is greater in infants and less in the aged.

An adult takes in about 2500 c. c. and excretes about 2600 c. c. daily. The excess of 100 c. c excreted, above that taken in, comes from the oxidation of the food or tissues. The proportion of water varies considerably in the various tissues and fluids of the body. The sweat contains 99.5 per cent.; the lymph 93 to 96 per cent.; chyle 90 to 97 per cent.; milk 86 to 90 per cent;

blood 78 per cent., as a mean; nerves 70 per cent.; brain 75 per cent.; muscles 76 per cent.; cartilage 55 per cent.; bones 22 to 40 per cent.; teeth 10 per cent.

Water is essential in carrying on the vital processes. It dissolves the substances intended for the nutrition of the tissues, as well as the waste products of their disintegration. It is thus the medium of all chemical reactions taking place within the body, and of the transfer of materials from one place to another. Water is one of the chief agents used by plants in building up the carbohydrates. It is also, in the animal, one of the chief agents used in the digestion, assimilation, and dissimilation of the proximate principles of foods. The water of the tissues may be reduced by hemorrhages, diarrhœa and other exhausting discharges. The person thus affected usually suffers intense thirst. and water should be supplied freely. It sometimes becomes necessary (hemorrhage, cholera) to supply the water by venous injections of a 0.75 per cent. salt solution.

Frogs die when they have lost an amount of water equal to 30 per cent. of their body weight; but they can live for two days in an atmosphere of pure oxygen, after all their blood has been displaced by a 0.75 per cent. salt solution. (Oertmann.) During this time they use the same amount of oxygen and exhale the same amount of CO_2 as in health. A considerable **increase of water** in the body is harmful, as it increases tissue waste, dissolves hæmoglobin from the red corpuscles, and thus reduces the oxygen-carrying power of the blood, and washes away the soluble saline matters. Injections of a great excess of water into the circulation may cause death.

A deficiency of water, if prolonged, leads to the accumulation of waste products in the blood and tissues, to deficient nutrition, often leading to constipation, dyspeptic symptoms, loss of weight, and rheumatic or gouty affections.

Hydrogen Peroxide has been found in the sweat and a few other fluids of the body.

Hydrogen Sulphide is found in the intestine as the result of the decomposition of bile and proteids by bacteria.

Ammonia is formed by the same decompositions, but it soon combines with acids to form salts.

Acids.—Free hydrochloric acid is found in the gastric juice.

Lactic Acid occurs in the stomach during digestion, and it is produced in the intestine along with butyric acid by the action of special ferments. **Sarcolactic Acid** is found in the juice of the muscles, during and after active contraction. The acidity of muscle increases for some hours after death.

Metallic Salts.—Dissolved in the fluids or combined with the organic substances composing the tissues, are found certain metallic salts, which play an important role in nutrition. They give to these organic substances new and special properties, such as solubility, dialysability, the power of solidifying as in tendons and bones, and the property of elasticity, resistance, etc. Iron and copper play a specific role in the constitution of certain bodies (nuclein, protoplasm, hæmoglobin, etc.).

Sodium Chloride is the most abundant of these saline bodies. We absorb and eliminate about 14 grams a day. Its principal function is to favor solution and osmosis of the proteid bodies, and it thus facilitates nutrition. It also facilitates the carrying away of the excrementitious matters formed by the activity of the cells. Common salt is necessary to the function of the various glands of the body. It enters into the composition of cartilage, bone, teeth, etc. A weak solution of this salt increases the solubility of most of the proteids. It increases the urinary secretion without increasing the elimination of urea. About 10 to 12 grams of $NaCl$ are excreted daily by the urine, besides that found in the perspiration, tears and fæces. Sodium chloride is more abundant than potassium chloride in the plasma of the fluids, while the latter is more abundant in the cellular elements.

Potassium chloride cannot take the place of sodium chloride.

Potassium Chloride is met with in the cells of every soft tissue, in the intercellular fluids, muscle juice, and nervous tissue. It seems to have a true stimulant action upon the activity of the cells. Plants have need of and contain more potassium than sodium salts. This is probably because the principal work of plants is constructive, which action is stimulated by potassium salts. Sodium chloride rather favors the dissimilation of cell waste. Herbivorous animals require some $NaCl$ to favor a good state of health.

The Calcium Salts are furnished by both food and drink. Lime gives solidity to the skeleton, and resistance to the whole body. It is the principal solidifying agent, and when the tissues degenerate it accumulates. In the disease called rickets and osteomalacia it is deficient in the bones, which are soft and easily bent.

Magnesium is found in the tissues with lime. Its special rôle is not well understood. It is a constant ingredient in brain matter, muscles, and the chlorophyll of plants.

The Sulphates are always to be found in the urine and in other fluids. H_2SO_4 is constantly prepared by the disintegrated and oxidized proteids, most of which contain sulphur About 70 per cent. of the sulphur of proteids appears as **phenol-sulphate,** skatoxyl-sulphate, or indol-sulphate in the urine. The sulphates of lime and magnesium are abundant in cartilage. We excrete by the urine from 1.5 to 2.5 grams per day of sulphuric acid combined as sulphates and ethers. They are increased by an animal and decreased by a vegetable diet.

The Alkaline Carbonates and **bicarbonates** exist in the lymph, chyle, saliva, bile, blood, etc. These salts of potassium exist in the blood and parotid saliva of herbivorous animals. It is the bicarbonate of sodium that gives most of the alkalinity to the blood and other liquids. With carnivorous animals the alkalinity is due to the phosphates and carbonate combined.

These salts are furnished by the food, especially as salts of the organic acids, which by oxidation are converted into carbonates. Both the absorption of oxygen and the oxidation of organic matters are favored by an alkaline medium. The bodies most easily oxidized in alkaline solution are the sugars, alcohols, organic acids, and then fats; the last being saponified, the glycerin and acid being oxidized separately.

Ammonium Carbonate is met with in traces in the blood. It appears in the blood, stools, and breath at the same time in cholera.

The Alkaline Phosphates are found in almost all tissues of the body. The phosphate of sodium, HNa_2PO_4 is the one to which the alkalinity of the blood is largely due. The potassium salt predominates in the blood-cells. The blood of omnivorous and carnivorous animals contains more phosphates than that of the herbivorous. The phosphates are eliminated principally by the urine in the form of neutral or acid phosphates of sodium, calcium, and magnesium. A little is excreted by the fæces, and a small amount in some other forms.

As we take a large part of our phosphates in our food, as the potassium salt, it is probable that the sodium salt is formed by the reaction of NaCl upon K_2HPO_4 in the blood and lymph. From this reaction there results the Na_2HPO_4 of the plasma, and KCl of the corpuscles.

In all actively growing parts of the body, in red and white blood-corpuscles, in muscles, nerve tissue, yolk of eggs, the seeds and young sprouts of plants, we usually find certain organic bodies, rich in phosphorus, such as lecithin, nuclein, legumin, etc.

The Earthy Phosphates are met with in the bones, teeth, and in less amount in certain tissues and in the urine.

The Carbonate of Calcium is found to a slight extent in bones and in the shells of mollusks. It sometimes occurs in solution as the bicarbonate, but often in the insoluble state.

This salt sometimes gives rise to concretions in the saliva, or upon the teeth, and in the labyrinth of the ear (otoliths).

Silica occurs in small quantity in both plants and animals, but its function has not been clearly made out. It has some well-defined use, and is found very widely distributed in both animals and plants.

Iron is found as an essential constituent of certain coloring matters, as hæmoglobin, yolk of egg, the pigments of the skin, hair, eyes, etc. The most remarkable compounds containing it are the hæmoglobin of the red blood-corpuscles and the nuclein, or the nuclei of the cells throughout the body. One thousand parts of the blood of man contain 0.56 part of iron; of beef, 0.51; of the goat, 0.33 part.

Most of our food and drink contains traces of iron, and our meats contain enough to satisfy our wants. It is eliminated by the bile and fæces. Iron compound seems to be the principal carrier of oxygen in the blood. We administer it to increase the hæmoglobin and the oxidizing power of the blood.

In vegetables, it enters into the composition of the protoplasm of cells, and possibly in the chlorophyll, although this is disputed. Iron seems to be essential to the growth of plants as well as of animals.

Copper enters into the composition of some plants and animals. As it always occurs in these organisms, it is safe to say that it has some unknown rôle to perform. In certain organisms it seems to replace iron. Copper is found to exist in many cereals and food products. Lead, manganese, silver, zinc, and other metals are frequently taken with food or drink, and that they exert some action on the economy is certain, although we are ignorant of their exact function.

THE FERMENTS.

Very many of the changes that take place in the body are produced through the agency of **ferments.** Not only do we have to do with those soluble active proteids which produce hydration of other compounds, breaking up complex molecules into simpler ones, but there are a number of such processes due to the action of certain microscopic organized bodies. It will be convenient, therefore, to give here some account of these ferments. They may be divided into two groups, the **soluble** and the **organized ferments.**

The **soluble** or **unorganized ferments,** or **enzymes,** are a class of albuminoid bodies which have the power, under favorable circumstances, of causing certain chemical changes in other bodies with which they are brought in contact, without themselves undergoing any change. They are called ferments because of the similarity of their action to that of yeast and other well-known ferments. Some of these bodies are of vegetable, while others are of animal origin. Those of vegetable origin are **diastase, emulsin, bromelin, papain,** and **myrosin;** while those of animal origin are **ptyalin** (salivary diastase), **pepsin, curdling ferment, pancreatic diastase, trypsin, invertin, histozym,** and probably others.

The exact chemical composition of these bodies is unknown, except that they are proteids. They are all soluble in water, are precipitated by alcohol and by lead acetate. They are very diffusible, lose their activity by being boiled with water, but are not precipitated. They have not yet been obtained in a state of absolute purity. The artificial preparations are mixtures of the true ferment with other products found with them in the digestive secretions. The soluble ferments are chiefly known under the collective name of **enzymes.** They are characterized by the fact that a very small quantity of the enzyme is capable of transforming a large amount of the substance acted upon. Their activity is dependent upon the temperature, being absent at very low temperatures, increasing as the temperature is raised to a certain point, which varies slightly in different enzymes, then again diminishing as the temperature is further raised, and at a sufficiently high temperature they lose their activity, the albuminoid basis being coagulated and precipitated. They are generally sensitive to a change of reaction in the solution in which they are acting, from alkaline to acid, or from acid to alkaline. Certain salts destroy their action, while others only retard it. Their activity is in all cases lessened, and finally stopped, by the presence of an excess of the products which they give rise to. They will stand a higher temperature when dry than when in the moist condition. They may even be heated in the dry state to 100° C. (212° F.) without permanent loss of their activity. Analysis shows their composition to be more nearly that of the proteids than of any other class of substances. The basis of most of the enzymes appears to be a proteose, while some behave more like an albumin. The only means at our disposal for determining the presence of an enzyme, is that of ascertaining the change it is able to produce in another substance.

The soluble ferments have a definite ascertainable limit of energy. Their power is used up in proportion to the work done, and the value of the ferment is generally estimated by determining the amount of food substance which it can convert, under fixed conditions. They are soluble in water, from which they are precipitated by an excess of absolute alcohol. In many cases they may be precipitated from their aqueous solution by saturation with $(NH_4)_2SO_4$. They are soluble in glycerin, from which they are precipitated by alcohol. They are not diffusible, and may be separated from diffusible substances by dialysis. They are prepared by cell action in certain portions of plants and animals, but in most cases the enzymes do not exist in the free or active condition in the cells, but in the form of an inactive antecedent, to which the name of **zymogen** is applied. It is frequently necessary, therefore, to treat the tissue with some reagent that shall convert the zymogen into an active enzyme, in order to obtain an active extract. The solutions of the enzymes readily undergo fermentation and putrefaction, and lose their activity. It is essential, then, to ensure the preservation of their activity in solutions, that some antiseptic be employed. The most suitable antiseptics for this purpose are chloroform (1 in 200), thymol (5 per cent.), salicylic acid (1 per cent.), and alcohol (15 to 25 per cent.). In order to distinguish between the soluble enzymes and an organized ferment, it is best to carry on the digestion in the presence of chloroform, which is inert toward an enzyme, but inhibits the growth and activity of organized ferments. Sodium fluoride (1 per cent.) entirely checks the growth of the organized, but is without action on the soluble ferments.

Diastase, or **Maltin,** is the ferment formed from the gluten in the cereal grains at the time of sprouting. Its chief object is the conversion of starch into dextrin and maltose. Ptyalin of saliva, and pancreatic diastase, if not identical with vegetable diastase, act in exactly the same way for a time, but the prolonged contact of these ferments changes the maltose to glucose, while malt diastase does not. They all act upon cooked starch with great rapidity, but have a very slow action upon raw starch. The process is one of hydration, and the action is similar to that which takes place when dilute sulphuric acid is boiled with starch or cellulose. When water is added to H_2SO_4 it probably forms

$H_6O_6S,(H_2SO_4 \cdot 2H_2O)$ or orthosulphuric acid. This acid, when boiled, tends to part with a portion of its water, and if starch or other easily hydrated compound be present, it imparts this water to that body, in the **nascent state,** so to speak. Diastase acts upon the starch at ordinary temperatures, in the same way that H_6SO_6 does at a higher temperature. The first effect is to thoroughly liquefy the starch, then convert it into dextrin, and finally the dextrin into maltose. The most probable explanation of how the change is effected is, that the enzyme combines with the starch to form a compound which reacts with water, and splits up into two simpler compounds—the one a hydrate of the starch, and the other the original enzyme itself.

Extracts of Malt, as met with in the market, are infusions of malted barley, sometimes containing dextrin, malt sugar, and dextrose. The bitter non-saccharine "malt extracts" of the market, as a rule, contain little or no diastase, and are simply weak beers, or infusions of malt.

A solid extract is now produced extensively, by evaporating an infusion of malt, generally in a vacuum at a low temperature. It should have a light color; the taste should be peculiarly sweet and the odor pleasant. The solution in nine parts of water should be only slightly turbid, and should give an abundant precipitate a few minutes after being mixed with an equal volume of picric acid. The insoluble matter should appear under the microscope as amorphous coagula and hexagonal prisms.*

The amount of starch that a given weight of diastase can transform is variously stated at from 2,000 to 100,000 times its own weight, which, however, seems to be a fixed quantity with any given specimen of diastase. The rapidity of its action seems to depend upon the relative proportions of starch and ferment present. When the ferment is present in large quantity, the action is very rapid, almost instantaneous; while if it is small in proportion to the starch, it is slower in action. Diastasic ferment does not exist in the saliva and pancreatic juice of infants, previous to the sixth or seventh month, in sufficient quantity to digest much starch. The digestive power varies greatly in different infants.

The Diastasic Value of Malt Extracts and Pancreatic Extracts.— The method of determining the diastasic value of malt extracts and of pancreatic extracts is as follows: A one per cent. solution of starch mucilage is employed. This is prepared by boiling 10 grams of any pure starch in water, cooling, and making up to 1 liter. Ten c.c. of this standard mucilage is mixed in a beaker with 90 c.c. of water. The mixture is then warmed to about 40° C. (104° F.), and a measured amount of the malt extract or pancreatic extract is added, the exact time of adding it being noted. At short intervals a drop of the mixture is placed upon a plate or white slab with a drop of a diluted aqueous solution of iodine. As long as starch is present in the solution, it will continue to give a blue color. When all the starch is converted into erythro-dextrin, a pink or brown color is produced. When all the erythro-dextrin disappears from the solution no color is produced with iodine. This has been termed the **achromic point.** This point should be reached at the end of not less than six minutes, in order that the end reaction may be determined with sharpness. When prolonged beyond this time the change is too gradual to be exactly determined.

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* Recently, a diastase of very high digestive power has been prepared by the action of a special ferment grown on wheat bran. The diastase is afterward separated, by treating the bran with water, and precipitating the solution with alcohol.

In the statement of the results we employ the following formula: $D = \frac{S}{P} \times \frac{5}{T}$ in which S = the weight of starch employed; P, the weight of pancreatic extract or malt extract employed; T, the observed time from the addition of the malt extract to the achromic point, and 5 the standard time in minutes. If, for example, 10 c.c. of the starch mucilage was taken and .1 grm. of a pancreatic extract was added, and the time required to reach the achromic point was 3 minutes, the above formula would become:—$D = \frac{10}{0.1} \times \frac{5}{3} = 166.6$ c.c. of the starch mucilage changed to the achromic point by 1 grm. of the extract in 5 minutes. As the mucilage solution contains 1 per cent. of dry starch, the 166.6 c.c. of this solution contains 1.666 grms. This method is equally applicable to malt diastase, salivary diastase, or pancreatic diastase. A good dry extract of malt should digest its own weight of starch in twelve minutes.

Emulsin or **Synaptase** occurs in sweet and bitter almonds. It may be extracted by digesting the almonds, freed from fat by pressure, for several hours, with water. The filtered liquid is acidified with acetic acid, to precipitate conglutin, and the emulsin is then thrown down with alcohol, filtered off, washed with alcohol, and dried. It is a white, friable mass, soluble in water, and capable of converting large quantities of amygdalin into sugar, prussic acid, and benzoic aldehyde; it also converts salicin into sugar and saligenin. Its aqueous solution readily decomposes, yielding lactic acid. A similar ferment has recently been found in certain parasitic plants, by which they are able to decompose glucosides found in the bark and feed upon them.

Myrosin is the ferment of mustard.

Pepsin, contained in gastric juice, is secreted by the glands of the stomach. It may be separated from the other constituents of filtered gastric juice by dialysis, as it does not diffuse through membranes. It is readily prepared by digesting the mucous membrane of the pyloric end of the stomach of the pig, first with strong alcohol, and after twenty-four hours expelling the alcohol by pressure, and digesting for some days with glycerin, slightly acidified with hydrochloric acid. It is filtered through muslin, then through paper, the pepsin precipitated with absolute alcohol, collected on a filter, and dried. Other methods are in use.

Pepsin is a yellowish or grayish-white powder, soluble in water and glycerin, but insoluble in alcohol. It gives few of the albumin reactions, and is precipitated by the acetates of lead. When dry, it may be heated to 110° C. (230° F.) without losing its activity, but its solutions lose it at a much lower temperature. Its activity is greatest at about 40° C. (104° F.), and requires hydrochloric, phosphoric, lactic, or other diluted acid to develop its peculiar action. The presence of 0.1 per cent. of NaCl favors its action, but more than 0.5 per cent. hinders it. Admixture of bile, carbolic acid, or an excess of alcohol retard or entirely prevent its action. Nearly all metallic salts diminish the action of pepsin. Calomel is an exception to this rule, as are also arsenious and arsenic acids. Many of the alkaloidal salts have a retarding effect, but the chlorides have less than the sulphates. Sugar has a retarding action. Sodium salicylate, antipyrin, antifebrin, paraldehyde, and thallin tend to stimulate the action of pepsin. Sodium carbonate quickly destroys it. The acid of gastric juice is mostly hydrochloric during the intervals of digestion, but during digestion several organic acids are set free by the hydrochloric acid from the acetates, malates, tartrates, etc., taken with the food, so that the real work of the digestion is accomplished with the aid of various organic acids instead of hydrochloric alone. The specific action of pepsin is the change of proteids, whether coagulated or not, into peptones. Peptone is scarcely altered by putrefaction.

The proteolytic activity of pepsin varies greatly according to the process of manufacture, and the care exercised.

The U. S. P. requires that the official pepsin shall digest 3,000 times its own weight of freshly coagulated and disintegrated egg albumin in six hours, when tested by the method given.

Valuation of Pepsin.—The digestive value of pepsin is a matter of considerable importance. The method of the U. S. P. requires the following three solutions:—

(a) To 294 c. c. of water add 6 c. c. of diluted HCl.

(b) In 100 c. c. of solution **a** dissolve 0.067 grm. (1 grain) of the pepsin to be tested.

(c) To 95 c. c. of solution **a**, brought to the temperature 40° C. (104° F.), add 5 c. c. of solution **b**.

Immerse and keep a fresh hen's egg for fifteen minutes in boiling water. Then remove and place in cold water. When cold, separate the white coagulated albumin, and rub through a clean sieve having 30 meshes to the linear inch, rejecting the first portion passing through. Weigh off 10 grms. of the second clean portion place in a flask of about 200 c. c. capacity, add ½ of solution **c**, and shake, to distribute the albumin evenly through the liquid. Then add the other half of solution **c**. Place the flask on a water bath, and keep the temperature at about 40° C. (104° F.) for six hours, shaking gently every 15 minutes. The albumin should have disappeared at the expiration of this time, leaving at most only a few, thin, insoluble flakes. The relative proteolytic power of pepsin stronger or weaker than that described above, may be determined by ascertaining how much of solution **b** made up to 100 c. c. with solution **a** will be required to exactly dissolve 10 grms. of coagulated and disintegrated albumin under the conditions given above.

The above method is somewhat cumbersome and tedious and there seems to be no fixed relation between the solution and digestion of the albumin. A better method is the following: Prepare two solutions:—

No. 1.—To 25 grms. of the well-mixed whites of several eggs add enough distilled water to make exactly 250 c. c. Mix well and boil the solution for 5 minutes. After cooling, make up the solution to the original volume with water. This solution contains 10 per cent. of egg white, or about 1.22 grms. of dry albumin in 100 c. c.

No. 2.—1 grm. of the pepsin to be tested is dissolved in 25 c. c. of water, 2 c. c. of diluted HCl (U. S. P.) is added, and enough water to make the solution up to 50 c. c.

Procedure.—Measure out into a beaker or bottle 50 c. c. of the albumin solution and warm on a water bath to about 40° C. (104° F.). Add to this 2 c. c. of diluted HCl (U. S. P.), and from 0.5 to 5 c. c. of the pepsin solution. The more active the pepsin, the less the quantity to be taken. It will sometimes be necessary, with an unknown pepsin, to make a preliminary test to determine the approximate time required by the digestion, as it is best to so regulate the quantity of pepsin and albumin, that the digestion should be complete in a little less than 2 hours. The time when the pepsin is added must be carefully noted, and the temperature kept at about 35° to 40° C. (95° to 104° F.). At intervals of 10 minutes draw out a few drops of the solution with an ordinary dropper pipette, and float it upon a few drops of pure HNO_3 in a narrow test tube. Note the time when the HNO_3 ceases to give a coagulum of albumin, or when the albumin disappears. We next assume the standard time of 3 hours, the average time of stomach digestion. The relation between the quantities of albumin and pepsin is expressed by the fraction $\frac{A}{P}$, *i. e.*, it is found by dividing the amount of albumin by the weight of the pepsin. This should be so regulated that the digestion is complete between 2 and 3 hours, in order to be comparable with the U. S. P. method. Egg white contains about 12.2 per cent. of dry albumin, but it varies considerably in different eggs, from 10 to 14 per cent. This method gives an exact statement of results, requires little if any skill in manipulation, and requires no shaking. The results are uniform when the time is about from 2 to 3 hours.

Trypsin occurs in the pancreatic juice, and may be extracted from the pancreas by a process similar to that described above for pepsin, except that no acid is used. Thus prepared, pancreatin is a yellowish-white, amorphous powder, soluble in water and glycerin, but precipitated by alcohol It possesses the property of acting upon the proteids in a way somewhat similar to pepsin, but is active only in alkaline solutions. The prancreatic juice contains a ferment called **steapsin** or **pialyn,** which is not soluble in glycerin, and is destroyed by acids and alcohol. It emulsifies and partially saponifies the fats.

A part of the peptone at first formed by the pancreatic juice is afterward converted into tyrosin and leucin. The digestion of the proteids is thus begun in the stomach, in an acid medium, and finished in the small intestine, in an alkaline medium. There is this difference in the two processes, that while acid pepsin readily liquefies the proteid bodies, it does not completely convert them into peptones; this completion of the process is more quickly and completely done by the trypsin (see under Albumoses). The secretion of Peyer's glands converts dextrin and maltose into glucose, but does not affect starch.

The diastase of the pancreatic juice, also called **amylopsin,** is identical in its action with the **ptyalin** of the saliva, and malt diastase, already described. Like these, it converts starch into maltose, but it acts better in the presence of bile than when alone. The method of determinating the diastasic value of pancreatic extracts is the same as that described above for malt extracts.

Rennin, or milk-curdling ferment, is found in the extract of the pancreas. It is not so abundant in this gland, however, as in aqueous and glycerin extracts of the mucous membrane of the stomach.

Nothing is known of the chemical nature of rennin. Under the name of **rennet**, it has been employed for centuries to coagulate the casein of milk in the manufacture of cheese. For this purpose it is usually prepared from the stomach of the calf, where it exists, in the form of **rennen zymogen**, which is converted by standing or by weak acids into rennin. It occurs in the stomachs of both children and adults. It has been found in small quantities in normal urine.

Fibrin-ferment.—The coagulation of paraglobulin in the formation of blood clot, is now believed to be caused by a special ferment.

It may be prepared by mixing blood serum with 10 to 15 volumes of strong alcohol, allowing it to stand 14 days, and filtering. The precipitate contains coagulated proteids with the ferment adhering to them. The ferment may be dissolved out by water. The blood in circulation does not contain the ferment, but it is formed by some change after the blood is drawn from the vessels; probably by the disintegration of the white corpuscles and the third corpuscle, or blood tablets.

It seems to be a globulin-like body. There are other globulins which have a similar action in the formation of fibrin, as this ferment. The **myosin** of muscle juice is especially to be mentioned as one of them. This is sometimes described as muscle enzyme.

Invertin is a ferment existing in the intestinal juice, which has the power of inverting cane sugar; *i. e.*, it converts it into dextrose and lævulose. Of its composition and other properties little is known. **Invertin,** or a substance possessing the same property, as well as a diastatic ferment, is found in the liquid portion of bakers' or brewers' yeast, after the cells have been killed by alcohol. While alive, the cells do not impart the invertin to the solution. It does not affect lactose, maltose, starch, or gums.

Histozym is a soluble ferment, supposed to exist in the blood, liver, and kidneys, and which has the power of causing a variety of reactions within the body, such as the conversion of benzoic into hippuric acid, etc.

Some authors have described certain other ferments under the name of **microzimas,** which act as active chemical and physiological agents in the body during life, and cause its decomposition after death. They appear as minute molecular granules, and are regarded as a part of the living organism by some, and as distinct organized ferments by others. As these molecular granules do not seem to undergo reproduction, and are not destroyed by antiseptics, it seems unlikely that they are organized structures.

Papaïn is a ferment prepared from the milky juice of the paw-paw tree. It is a white, amorphous, granular powder. It is soluble in water and glycerin. This ferment peptonizes proteids very rapidly, the end product being leucin, and coagulates milk. It acts like trypsin. It has been used to digest the membrane of croup and diphtheria. Hydrochloric acid lessens its action, as does carbolic acid, but they do not arrest it. It can act in an alkaline, neutral or feebly acid solution. Under the name of **papoid** it is found in the market as a remarkably active digestive agent. It resembles in its action the trypsin of pancreatic fluid.

Bromelin is the name given to a proteolytic ferment of pineapple juice.

It appears to be associated with a peculiar proteose-like substance. It acts upon fibrin, albumin and myosin to produce proteoses and peptones.

Similar proteolytic ferments have been found in the juice of the fig-tree, in the fruit of *cucumis utilissimus*, a plant found in India, and in certain seedlings as barley, poppy, maize, wheat, rye, etc.

ORGANIZED FERMENTS.

Somewhat similar in action to the preceding group of ferments, are certain forms of low vegetable organisms, which are known as **organized ferments.** These organisms vegetate most readily at temperatures of from 20° C. (68° F.) to about 40° C. (104°F.). Temperatures above or below these limits retard their growth, while a temperature near the boiling point entirely destroys their activity. A very minute quantity of any of these ferments can grow and exert its peculiar action, as long as its peculiar nourishment lasts, and proper conditions of its life are maintained. Organized ferments excite chemical changes, as the direct physiological result of their growth. They are all killed by hydrogen peroxide, and the chemical change is stopped by it. All physiological fermentations in the organism are caused by the soluble ferments, while pathological fermentations are caused by the organized ferments. The **antiseptic** agents are, as a rule, **antifermentatives,** check the growth of and in many cases kill the organized ferments. (See p. 166.) The changes produced by the enzymes may be distinguished from those produced by organized ferments by the addition of chloroform or sodium fluoride (1 per cent.), both of which check the growth of organized ferments, while the action of enzymes is not interfered with.

The most important of the ferments of this class are yeast, or alcoholic ferment, acetic acid ferment, lactic, butyric, and putrefactive ferments. With the exception of the first of these organisms, they all belong to the bacteria family.

Yeast (Torula, or **Saccharomyces cerevisiæ)** consists of one-celled, globular or oval-shaped microscopic plants, multiplying by budding. There are several varieties of this fungus. The principal action caused by yeast in saccharine fluids is, first, to convert the saccharose into invert sugar, and then change this into alcohol, carbon dioxide, and a trace of succinic acid and glycerin. The spores of yeast are always to be found either in the air, or upon the surface of fruit, whence they find their way into the solutions made from their juices, which explains the apparent spontaneous fermentation. Invertin accompanies the growth of yeast. It has the power of inverting cane sugar. (See p. 549.)

Acetic Acid Ferment (**Mycoderma Aceti**) occurs usually in the form of chains of very small globular bodies, formed by the multiplication of the cells by divisions, at right angles to the line of growth. It belongs to the bacteria family. It grows in alcoholic solutions containing a small amount of albuminous matter or ammoniacal salts, and alkaline and earthy phosphates. A little acetic acid favors its growth, as well as a free supply of air. It acts by causing an oxidation of the alcohol to acetic acid; when this change is complete, the ferment dies for want of nourishment.

Saccharomyces Albicans (**Oïdium Albicans**) is the ferment which is found growing upon the mucous membrane of the mouth of infants, producing the disease known as "thrush" or "sprue." The fungus appears as white patches upon the tongue and other parts of the mouth. The cells are globular, oval, or cylindrical, and occur in colonies or rows. It excites alcoholic fermentation but feebly.

Lactic and **butyric** fermentations go hand in hand, the former usually, if not always, preceding the latter. They thrive best in a neutral or alkaline medium, and grow best without oxygen, at a temperature of 35° C. to 40° C. (95° F. to 104° F.). These conditions exist in the intestines, and they are always found there. The substances most prone to these fermentations are sugars, organic acids, soluble proteids, and especially mucus. The products of the fermentation are lactic, acetic, and butyric acids, carbon dioxide, and free hydrogen. These gases distend the bowel and often produce colic. Any excessive production of mucus in the bowel, greatly favors these fermentations.

The growth of the **Bacillus butylicus** furnishes a soluble ferment which has the power of inverting cane sugar and slowly peptonizing albuminoids, but it does not hydrolize either lactose or starch.

Urea-ferment.—When urine is exposed to the air, its acidity at first increases, and then diminishes rapidly, and gives way to an alkaline reaction. The solution is then found to contain ammonium carbonate, formed from the urea. This is due to a hydrolytic change resulting from the growth of certain microorganisms, of which the best known is the **torula ureæ.**

Recent investigations seem to prove that these organisms are not the only agency that brings about this change, but that there is probably a soluble enzyme tha assists them, or may even perform the conversion without the presence of the organisms.

It is quite certain that the mucus secreted in catarrh of the bladder can produce the change, as it takes place in the presence of chloroform and of sodium fluoride. If a urine which is full of torula be filtered through a filter that allows no organisms to pass, the change is stopped. If it be treated with alcohol before filtering, the filtrate has the power of producing the change. It thus seems that the alcohol extracts an enzyme from the torula, while water does not. The most prolific source of this enzyme is the mucus of cystitis.

Putrefactive Fermentation is caused by the growth of various forms of bacteria. The proteids are most liable to putrid fermentation. This fermentation takes place in all organic infusions containing proteid matters, when exposed to the air; it also occurs in the small intestine, in cases of constipation or in some forms of indigestion, and to a slight extent, in the normal conditions. The putrefactive ferments are classified into **aërobic** (those requiring oxygen), and **anaërobic.** The first give a little gas, little or no ammonia, and odorous products. The second class decompose the proteid matters, producing at first hydrogen, and a little carbonic, acetic, lactic, and butyric acids. Then the matter becomes strongly alkaline from the production of ammonia, with escape of nitrogen, ammonia, hydric sulphide, and complex phosphorous compounds. At the end of some days the mass gives off almost pure CO_2 and NH_3, and there goes into solution a series of amins and amids, among which are amido-stearic acid, leucin, tyrosin, caproic, butyric, and palmitic acids. The two last predominate. At the same time phenol, skatol, indol, pyrrol, and phenyl-acetic, phenyl-propionic, oxyphenyl propionic, skatol-carbonic, and skatol-acetic acids make their appearance. Finally, more or less poisonous toxalbumins, peptone, and ptomaïnes appear. These products do not all appear in all cases, but are modified by the subs ance acted upon, and other conditions.

Nitrifying Ferment.—This ferment consists of certain microörganisms found in all soils containing organic matter, and found especially abundant about the rootlets of plants. They are also found in surface waters. Their function is to convert albuminoid matters and ammonia into nitrous and nitric acids. They therefore act as oxidizing agents, similar to the acetic ferment. It is by this agency that polluted waters dispose of their nitrogenous organic matter, and purify themselves.

When a water has thus purified itself, the nitrogen will be found in the form of nitrates, or nitrites of the metals. (See Water Analysis.)

It is by the aid of these organisms that plants are able to feed upon albuminoid matters in the soil, and it is claimed that they can fix the free nitrogen of the air, and make a plant food of it.

Disease-Producing Organisms.—The organisms of the contagious and infectious diseases belong in this class of organized ferments. They are believed to owe their peculiar action on the body to the peculiar toxins which they produce while multiplying in the fluids. In many cases it has been proven that the toxins which the microbes secrete, and which are precipitable with alcohol, are the active agents. When injected into the circulation, they produce, with or without fever, a state of resistance to the growth of the microbe, or its effects, called immunity. (See Toxins.)

NUTRITION.

As has already been stated, animals derive their nourishment from the vegetable kingdom, either directly, or they live upon animals who, in turn, live upon a vegetable diet. Foods are substances which are required for the nutrition of the body. It has been calculated that the average adult man loses about 1000 grms. of solid matter daily, in the expired air, sweat, urine, fæces, and other excretions. Food is necessary to replace this waste, if the body weight is to remain constant.

Nutrition takes place in five different phases, viz.: digestion, absorption, assimilation, destructive metabolism, and elimination of waste, or excretion. **Digestion** is the process of converting food into dialyzable compounds. Digestion is followed by **absorption,** that is, the passage of the products of digestion through the walls of the alimentary canal into the blood and lymph, which carry the absorbed material to the tissues. The tissues take up the digested and absorbed material for the nutrition of their cells. This is called **assimilation.** In some cases assimilation is delayed by the storing up of materials for future use, such as the storing of glycogen in the liver and of fat in the connective tissue. **Destructive metabolism** is the process continually going on in the tissues, by which they are disintegrated during the physiological activity of the cells. It is chiefly a process of oxidation, the oxygen being supplied by the respiration, and the energy of this oxidation is used up in the physiological activity of the tissues and the production of heat. By this process stored energy is converted into muscular or nerve energy. The **elimination of waste** products is the discharge from the system of the products of the destructive metabolism. These waste products are no longer required in the system, as their energy has been used up.

FOODS AND DIET.

Foods are mixtures of various inorganic and organic materials, which are usually termed by the physiologists **proximate principles.** The chief proximate principles of food are the same as the chief proximate principles of the body. They may be classified as follows: Water, metallic salts, proteids, gelatinoids, fats, carbohydrates, and a few other less important organic constituents. These proximate principles do not occur in natural foods in the pure state, but are mixed in varying proportions in the different foods. It is necessary, in a suitable diet for man, that all these above-mentioned proximate principles should exist; and hence we find them mixed for use in natural foods. In milk and eggs, for example, which form the exclusive food-stuff for young animals, we find all the proximate princples mixed in suitable proportions; hence, they are frequently spoken of as perfect foods. Eggs, although a perfect food for birds, are not quite perfect for mammals, as they contain too little carbohydrates. In vegetable foods, as a rule, the carbohydrates predominate, and are, therefore, necessarily mixed with fat and nitrogenous substances in the form of animal food.

Diet.—A healthy and suitable diet must possess the following characteristics: 1. It must contain the proper amount and proportions of the various proximate principles; that is, of proteids, fats, carbohydrates, salts, and water. 2. It must be adapted to the age, sex, and habits of the individual, and to the climate. 3. It must not only contain the proper proximate principles, but they must be in a digestible form. 4. The object of food being to nourish the tissues and repair the loss due to destructive metabolism, the relation between food, exercise, and excretion must, therefore, be properly regulated.

In the consideration of diet, it is usual to consider chiefly the three proximate principles, carbohydrates, proteids, and fats. It is necessary that these three ingredients should be adjusted so that neither should be in great excess over and above the needs of the body. The proportion of carbon to nitrogen in proteids is about as 15 to 53, or 1 to 3.5. If a person live entirely on proteid food, his diet will contain too much nitrogen and too little carbon. If he live entirely upon carbohydrates, he would not get sufficient nitrogen to nourish the tissues. The fats and carbohydrates taken together are sometimes called the non-nitrogenous foods. In carbohydrates the H and O exist in the proportion to form water. We may regard the H, therefore, as completely burned in his body, and not available for combustion or the generation of energy, the carbon alone being available for that purpose. Fats contain much less O in proportion to their carbon and H than do the carbohydrates; they, therefore, generate more heat in their complete oxidation than the latter. It is found that animals thrive best on diets which supply them with the bulk of their carbon from both fats and carbohydrates. The diet which man constructed for himself, long before theories explained why he did so, contained both carbohydrates and fats. Again, the foods which nature has provided for growing animals, in the shape of milk and eggs, contain fat, the carbohydrates and proteids. From this it would be inferred, that all three of these constituents are essential for the proper nourishment and growth of animals.

Dynamic Energy of Foods.—Heat and muscular power, or dynamic energy, is one of the important offices of all food. The general result of the chemical changes going on in the body, sometimes termed metabolism, is chiefly an oxidation process. The oxidation of organic matter always develops more or less heat energy. Heat and muscular power are convertible in the body, and articles that produce heat produce also muscular energy.

Energy is usually reckoned either in terms of work done, or as its equivalents in heat units. The unit of work is the foot-pound or foot-ton in English measure, or the gram-meter or kilogram-meter in the metric system. The heat unit, or **calorie**, is the amount of heat necessary to raise the temperature of one kilogram of water from zero to 1° C. In English measures a thermal unit is the amount of heat necessary to raise 1 pound of water from 0 to 1° C.*

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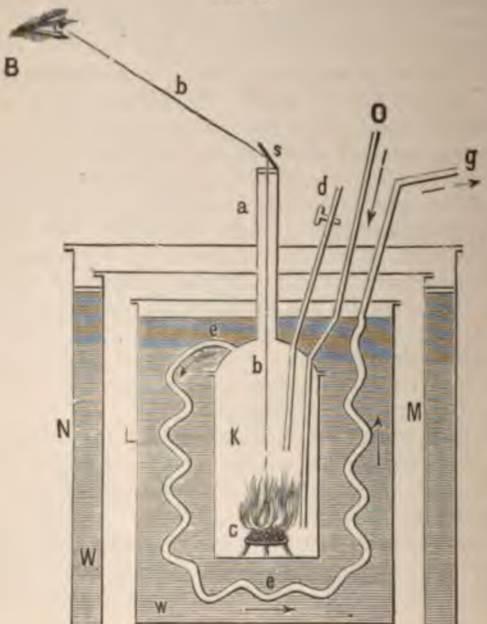
* A thermal unit is sometimes taken as the heat necessary to raise one pound of water 1° F. A smaller calorie is sometimes used, which is the heat required to raise 1 grm. of water 1° C.

A thermal unit = .45 calorie.
A calorie = 2.2 thermal units.
A thermal unit = 1390 foot-pounds or 0.695 foot-ton.
A calorie = 425.5 kilogram-meters, or 425,500 gram-meters.
A calorie = 3077.6 foot-pounds.

1 Kilogram-meter = 7.233 foot-pounds.
1 Foot-pound = 0.138 kilogram-meter.

The heat of combustion is the same, whether the food be burnt in the air or in the human body. The apparatus which is employed for determining the heat of combustion of bodies, Fig. 63, consists of a vessel surrounded by a known weight of water, and in which the substance is burned with oxygen. The heat is communicated to the surrounding water, and the rise of temperature of the water is carefully measured with a thermometer. It is called a **calorimeter**. The substance to be burned is placed in the combustion chamber, *k*. This chamber is suspended in

FIG. 63.



the larger vessel *L*, filled with water, which completely surrounds the combustion chamber. The vessel containing the water is surrounded with a layer of non-conducting material, *M*, and then put inside of a larger vessel containing water. The combustion chamber has three tubes passing into it; *o* supplies air to support the combustion; *a* is an observation tube; *d* is used to conduct gases when these are to be burned, and *g* leads out the gases produced by the combustion, and is made to traverse the water through a long distance, so as to cool the gases thoroughly. A weighed quantity of the substance can be burned in the calorimeter, and the heat produced is estimated by noting, by a delicate thermometer, the number of degrees in temperature, the known weight of water in the instrument is raised. By means of the calorimeter we are able to determine the amount of heat produced by the combustion of the food or food constituents.

The following are some of the results obtained in this way:—

NAME OF PRINCIPLE.	POUNDS OF WATER RAISED 1° F.	CALORIES.	POUNDS RAISED 1 FT. HIGH (FOOT LBS.).
10 grs. glucose, ...	8.42 =	3.79	6500
10 grs. milk sugar, ...	8.63 =	3.88	6651
10 grs. lump sugar, ...	8.61 =	3.86	6647
10 grs. arrowroot, ...	10.6 =	4.77	7766
10 grs. butter, ...	18.60 =	8.37	14,421
10 grs. beef fat, ...	20.91 =	9.41	16,142

These numbers were obtained with the respective foods in the natural state. When absolutely dry, fat is found to give 2.5 times as much heat as starch or sugar.

The following proximate principles, when burned, give the following amounts of heat and work:—

	CALORIES.		FOOT-TONS.	KILOGRAM-METERS.
	Per gram.	Per ounce.		
Proteid, . . .	4.2	116.26	6.4	1787
Fat, ...	9.3	263.70	14.2	3957
Carbohydrate, .	4.1	116.25	6.3	1744

Dr. Rubner obtained, by comparative feeding experiments upon animals, and with the calorimeter, the following figures. Taking the thermotic value of fat at 100, he found that to give the same amount of heat it required:—

	BY FEEDING EXPERIMENTS.	BY CALORIMETER.
Myosin, ...	225 parts.	213 parts.
Lean meat, ...	243 "	235 "
Starch, ...	232 "	229 "
Cane sugar, ...	234 "	235 "
Grape sugar, ...	256 "	255 "

That is, 1 gram of fat gives the same amount of heat as 2.25 grams of myosin, or as 2.56 of grape sugar. From these or similar experiments, it is possible to arrive at a definite estimation of the potential energy produced by foods. It has been found that the heat value of proteids, when completely burned, is equal to that of carbohydrates, and is, therefore, a little less than one-half the value of fat, as heat-producing agents. It must be remembered, however, that there is this difference: that lean meat has for one of its chief offices the building up of tissue and repairing waste. We do not, therefore, obtain all the possible heat and muscular power from it, as we do from the carbohydrates and fats. About one-third of its heating power remains in the urea which is formed from it. In accurate experiments in feeding the human body, it has been found that the proteids, fats, and carbohydrates replace one another in almost the exact proportion of their heats of combustion, when the person experimented with is in a state of idleness. The following table, arranged by Frankland, gives the force produced by 1 gram of the common articles of food:—

FOOD.	PERCENTAGE OF WATER.	FORCE-PRODUCING VALUE.		
		IN CALORIES.	IN KILOGRAMMETERS.	
			When Burnt in Oxygen.	When Burnt in the Body.
Cod-liver oil,	......	9.107	3857	3857
Beef fat,	......	9.069	3841	3841
Butter,	......	7.264	3077	3077
Cheshire cheese,	24.0	4.647	1969	1846
Oatmeal,	......	4.004	1696	1665
Flour,	......	3.936	1669	1627
Pea-meal,	......	3.936	1667	1598
Arrow-root,	......	3.912	1657	1657
Ground rice,	......	3.813	1615	1591
Yolk of egg,	47.0	3.423	1449	1400
Cane sugar,	......	3.348	1418	1418
Hard-boiled egg,	62.3	2.383	1009	966
Bread crumb,	44.0	2.231	945	910
Mackerel,	70.5	1.789	758	683
Lean beef,	70.5	1.567	664	604
Potatoes,	73.0	1.013	429	422
Whiting,	80.0	0.904	383	325
White of egg,	86.3	0.671	284	244
Milk,	87.0	0.662	280	266
Apples,	82.0	0.660	280	273
Cabbage,	88.5	0.434	184	178

The following table gives the calorific value of 100 grammes and of 1 ounce avoirdupois, and will be found useful in calculating dietaries:—

CALORIFIC VALUE OF 100 GMS., AND 1 OZ. OF SOME STANDARD FOODS (Jürgensen).

	Calories.	
	Per 100 gms.	Per oz.
Whole milk,	67.5	19.3
Skim milk,	39.61	11.3
Cream,	214.7	61.34
Buttermilk,	41.56	11.8
One egg,	80.	2.29
Buttered egg,	187.6	53.6
Wheat bread,	281.	80.
Wheat bread (toasted),	258.8	74.
Zwieback (wheat),	357.8	100.2
English biscuit,	419.9	119.9
Cakes,	374.	107.
Butter,	814.	231.
Beef (raw),	118.95	33.5
Beef (broiled),	213.6	61.1
Beef (boiled),	209.	60.
Veal cutlets (raw),	142.45	40.7
Veal cutlets (broiled),	230.5	65.9
Chicken breast (raw),	106.4	30.4
Pigeon (raw),	99.7	28.48
Calf brains (raw),	140.	40.
Carp (raw),	93.	26.57
Flounder,	100.6	28.74
Salmon,	133.3	35.23
Sole,	95.2	27.2
Trout,	106.4	30.4
Potato bread (with butter),	127.4	36.4
Spinach,	165.65	47.33
Carrots,	41.	11.7
Bean soup,	193.	55.14
Green peas,	318.	62.3
Asparagus,	18.5	5.5
Oat meal,	288.5	82.4
Macaroni,	352.6	100.7
Omelet,	236.7	67.62

The calorific value of any food may be calculated from its proximate composition, by multiplying the per cent. of proteid, fat and carbohydrate, by the amount of heat developed by 1 gramme or 1 ounce of each, and adding together these products As percentage represents parts in 100, the above calculation will give the heat to be obtained from 100 grms. or 100 ozs. according as the factors for 1 grm. or 1 oz. were used.

Diet Tables.—The proper construction of the diet for man has been made the subject of a great deal of investigation, and is a matter of considerable importance. The attempt has been made in various ways to determine the necessary daily diet of a man under different conditions. Moleschott fixed the following daily diet for a man performing a moderate amonnt of work :—

Food.	Nitrogen in Grms.	Carbon in Grms.
120 grms. (4.23 oz.) proteid, containing . . .	18.88	64.18
90 " (3.17 oz.) fat, " . . .	0.	70.20
330 " (11.64 oz.) carbohydrates, containing	0.	146.82
Total, ...	18.88	281.20
Total in grains, ...	291.13	4336.2

Ranke, by experiments upon himself, determined upon the following as the necessary daily diet :—

	Nitrogen in Grms.	Carbon in Grms.
100 grms. proteids, containing	15.5	53
" " fat, "	0.	79
250 " carbohydrates, containing	0.	93
Total, ...	15.5	225
Total in grains, . . .	239.	3469.5

Dr. E. Smith gives as a fairly sustaining, or famine diet :—

	Carbon.	Nitrogen.
For an adult man, ...	4300 grs.	200 grs.
" " " woman, ...	3900 "	180 "
The average adult requires, ...	4100 "	192 "
An adult in idleness requires of nitrogenous food 2.67 oz., and of carbonaceous food 19.61 oz., which equals	3816 "	180 "
For short ordinary labor 4.56 oz. nitrogenous, 29.24 oz. carbonaceous, which equals . .	5688 "	307 "
Active labor, 5.81 oz. nitrogenous food, 34.97 oz. carbonaceous food, or . . .	6823 "	391 "

Playfair, Ranke, Beigel, Vogel, and others give the daily average of N for average labor as 252 grs., and at rest 171 grs.

The following table gives the amount of food which will contain the average daily needs of the human body, according to Moleschott's estimates :—

Food.	Weight of Food which Contains	
	120 grms. of proteid.	420 grms. of non-proteid (90 of fat, 330 of carbohydrates).
Cheese,	350 grms.	1530 grms.
Lentils,	453 "	693 "
Peas,	537 "	704 "
Beef,	566 "	1945 "
Hens' eggs,	893 "	776 "
Wheat bread,	1332 "	543 "
Maize,	1515 "	643 "
Potatoes,	6000 "	1751 "

The following table gives the results arrived at by different investigators, as to the necessary daily amounts of the three proximate principles demanded by adults in different conditions, with the calories generated by these quantities. To convert this last column into the equivalent in work it is only necessary to multiply the number of calories by 3077 to reduce it to foot-pounds, or by 1.539 to get foot-tons:—

EUROPEAN DIETARIES.

	Proteids.	Fat.	Carbohyd'te.	Calories.	Author.
Soldier in peace,	119	40	529	2784	Playfair.
" light service,	117	35	447	2424	Hildesheim.
" in the field,	146	44	504	2852	"
Laborer,	130	40	550	2903	Moleschott.
" in idleness,	137	72	352	2458	Pettenkofer & Voit.
Carpenter (40 years),	131	68	494	2835	Forster.
Young physician,	127	89	362	2602	"
" "	134	102	292	2476	"
Laborer, servant,	133	95	422	2902	"
English smith,	176	71	666	3780	Playfair.
" prize-fighter,	288	88	93	2189	"
Wood-chopper (Bavarian)	135	208	876	5589	Liebig.
Laborer (Silesian),	80	16	552	2518	Meinert.
Seamstress (London),	54	29	292	1688	Playfair.
Soldier in peace,	130	40	551	2900	Hammersten.
" war,	146	59	557	3250	"
Average population (Paris)	115	48	333	2219	Gautier.

AMERICAN DIETARIES (Expressed in Pounds Avoirdupois).

	PRO-TEIDS.	FAT.	CARBO HYD'TE.	CALOR-IES.	AUTHOR.
Family of carpenters, . .	0.25	0.28	0.76	3.055	Atwater.
" glass-blowers, .	0.23	0.29	1.06	3.590	"
Operatives in cotton mills,	0.29	0.44	1.21	4.650	"
Well-paid machinists, . .	0.23	0.44	0.84	3.490	"
Average of 20 dietaries of wage-earners (Mass. and Conn.), ...	0.34	0.50	1.38	5.275	"
Average of 5 dietaries of college students and professional men, Middletown, Conn., ...	0.27	0.34	1.08	3.925	"
Brickmakers, at hard work	0.40	0.81	2.54	8.850	"
Standard dietary in Mass. and Conn. with moderate work, ...	0.28	0.28	0.99	3.520	"
Standard for hard muscular work, ...	0.39	0.55	1.43	5.700	"

Taking the figures in the last column, rejecting those which are exceptionally high or low, we find that the average European dietaries give about 2800 calories, and the average American dietaries give about 3500 calories.

Calculation of Daily Dietaries.—From the data above given it is an easy matter to arrange a mixture of foods to give the necessary daily energy demanded by persons in any desired condition.

This is an important matter to the physician, as he is frequently called upon to arrange dietaries for prisons, asylums, soldiers and other collections of individuals. It is frequently desirable to prepare a dietary for the purpose of increasing or diminishing flesh or in the treatment of certain diathetic diseases. We will give an example of the method of calculating a diet table to consist of beef, bread, butter, oatmeal and potatoes, and to furnish approximately 3500 calories of heat.

Beef (weighed raw), ...	14 oz. =	469	calories.
Wheat bread, ...	20 "	1800	"
Butter, ...	3 "	693	"
Potatoes, ...	10 "	235	"
Oatmeal, ...	3 "	247	"
Total, ...	50 oz. =	3,444	"

We may reduce any one of these articles and replace it by another article. Suppose it be desired to reduce the meat by 2 ounces, and replace it with sugar. The 12 ounces of beef would give 402 calories. The difference, 469—402=67 cal , must be replaced by sugar giving 116.25 cal. per oz. 67.÷116=0.58 oz. of sugar required to replace 2 ounces of raw beef.

The following is a dietary devised by Austin Flint, and adopted by the New York State Commission in Lunacy, and used in all the state hospitals:—

DAILY RATION.

			CALORIES.
Meat, with bone, including salted meats, fresh and salted fish, and poultry,	12	oz.	450
Flour, to be used in making bread and in cooking (may in part be substituted by corn meal and macaroni),	12	"	1233
Potatoes,	12	"	240
Milk,	16	"	325
One egg,	2	"	80
Sugar,	2	"	230
Butter,	2	"	450
Cheese,	1	"	130
Rice, hominy or oatmeal,	1½	"	173
Beans or peas (dried),	1½	"	150
Coffee (in the berry and roasted),	5/6	"	
Tea (black),	1/8	"	
Approximately,			3,461

We have discussed the dynamic value of foods largely as to the amount of heat produced by their combustion. Muscular energy is derived from the conversion of this heat into dynamic energy. It is easy to calculate from the heat generated by a food, the muscular power it will produce. We have but to multiply the number of calories by 3077.6 to get the equivalent in foot-pounds, or by 425 5 to get the equivalent in kilogram-meters.

If we take the European estimate for adults not doing work, as 2400 calories, we calculate the equivalent in work as 1,020,000 kilogram-meters or 3670 foot-tons. For ordinary work the heat required is estimated at 2800 calories, 1,200,000 kilogram-meters, 4280 foot-tons, or 8,562,400 foot-pounds. Taking the American estimate for ordinary work of 3500 calories, we calculate the equivalent as 1,488,250 kilogram-meters or 10,771,600 foot-pounds.

It must not be supposed that all the work represented by these figures can be produced by a man by using the above diets.

A considerable part of the energy of the food is used up by the work of the heart and lungs, and necessary muscular movements, and a part is lost by radiation of heat from the surface of the body, and a part is lost with the breath, perspiration, urine, and fæces.

McKendrick puts the amount of work done by a laborer in 8 hours as 125,000 kilogram-meters, or 904,125 foot-pounds. The average daily amount of work performed by laborers is about 1 million foot-pounds. About one-half as much can be accounted for in other work, leaving about four-fifths of the energy of the food taken, as loss. The best steam engine can utilize about one-eighth of the total energy of the fuel, while the human body gives about one-fifth of the total energy of its fuel in the form of muscular power. It has been estimated by Prof. Gohren that the horse may transform about 32 per cent. of his food into energy, an ox 43 per cent., a man 53 per cent. These results are higher than those of most other observers. The experiments by Rubner on dogs, show that they use the fuel with great economy as long as it is not given in excess over the needs of the body. If, however, more food was given than their bodies required, they stored up a part of the excess as fat for a time, but finally reached the point where the excess was all wasted: *i. e.*, there seemed to be a limit to their storing up of fat, and after that the excess taken was thrown away.

COMPOSITION OF COMMON FOODS. *Gautier.*

NAME OF FOOD.	1 ALBUMINOIDS AND EXTRACTIVES.	2 FATS.	3 CARBOHYDRATES.	4 ASH.	5 WATER.	6 REFUSE.	RATIO OF 1 : 2 : 3		
							1	2	3
Flesh without Bones:—									
Beef, fat,	183	166	.	11	640	. .	1	.9	0
" medium fat,	196	98	.	18	688	. .	1	.5	0
"	190	120	.	18	672	. .	1	.63	0
" salted,	218	115	.	117	550	. .	1	.53	0
Veal,	190	80	.	13	717	. .	1	.42	0
Horse-flesh,	318	65	.	125	492	. .	1	.20	0
Smoked ham,	255	365	.	100	280	. .	1	1.43	0
Pork, salted and smoked,	100	660	.	40	130	. .	1	6.60	0
Flesh with Bones:—									
Beef, fat,	156	141	.	9	544	150	1	.90	0
" medium fat,	167	83	.	15	585	150	1	.49	0
" slightly salted,	175	93	.	85	480	167	1	.53	0
" corned,	190	100	.	100	430	180	1	.53	0
Mutton, very fat,	135	332	.	8	437	88	1	2.46	0
" medium fat,	160	160	.	10	520	150	1	1.	0
Pork, fresh, fat,	100	460	.	5	365	70	1	4.60	0
" salt, fat,	120	540	.	60	200	80	1	4.50	0

COMPOSITION OF COMMON FOODS.—*Continued.*

NAME OF FOOD.	1 ALBUMINOIDS AND EX-TRACTIVES.	2 FATS.	3 CARBO-HYDRATES.	4 ASH.	5 WATER.	6 REFUSE.	RATIO OF 1 : 2 : 3		
							1	2	3
Flesh with Bones:—									
Ham, smoked,	200	300	.	70	340	90	1	1.50	.0
Eggs, white,	103	7	7	8	875	. .	1	.07	.07
yolk,	160	307	.	13	520	. .	1	1.92	.
Milk, cow,	36	40	55	4	865	. .	1	1.11	1.53
human,	19	45	53	1.8	877	. .	1	2.37	2.52
Fish in General,	135	45	.	15	740	. .	1	0.33	. .
Eel, of rivers (entire),	89	220	.	6	352	333	1	2.47	. .
Salmon (entire),	121	67	.	10	469	333	1	0.56	. .
Sole, "	145	14	.	11	580	250	1	0.09	. .
Perch, "	100	2	.	8	440	450	1	0.02	. .
Cod (fresh), entire,	86	1	.	8	455	450	1	0.01	. .
Herring (salted),	140	140	.	100	280	340	1	1.	. .
Salmon "	200	108	.	132	460	100	1	0.54	. .
Cod (dried),	532	4	.	106	257	100	1	0.01	. .
Vegetable Foods:—									
Wheat bread (fresh),	88	10	550	17	330	5	1	0.11	6.25
Rye " "	77	10	480	16	400	17	1	0.14	6.25
Wheat,	146	12	679	16	140	. .	1	0.082	4.68
Rye,	90	20	675	19	166	. .	1	0.22	7.50
Winter barley,	134	28	636	45	130	. .	1	0.21	4.74
Oats,	119	55	615	30	140	. .	1	0.46	5.17
Corn,	128	70	599	11	177	. .	1	0.54	4.69
Rice,	64	4.3	781	6.8	144	. .	1	0.06	11.90
Peas,	225	20	575	23	145	.	1	0.09	2.55
French beans,	225	20	540	24	160	. .	1	0.09	2.43
Kidney "	220	15	575	25	130	. .	1	0.07	2.61
Lentils,	265	25	580	16	115	. .	1	0.09	2.19
Potatoes,	15	2	200	10	760	. .	1	0.09	10.30
Cauliflower,	5	. .	20	7	920	. .	1	. .	4.00
Apples,	5	. .	20	. .	. .	. .	.	. .	. .
Grapes,	7	. .	80	5	820	. .	1	. .	16.00
Almonds,	242	537	72	29	54	66	1	2.22	0.30
Cocoa,	140	480	180	50	55	95	1	3.43	1.29
Prepared Foods:—									
Bouillon,	6	. .	.	3	985	. .	.	. .	. .
Butter,	7	850	.	15	119	. .	1	1.21	.1
Lard,	3	990	.		7	. .	1	3.30	.0
Swiss cheese,	335	250	.	38½	346	. .	1	0.75	.0
Parmesan cheese,	441	159	.	57	275	. .	1	0.36	.0
Extract of beef (Liebig's),	304	. .	.	175	217	. .	.	. .	. .
Wine (red Bordeaux),	. .	. .	83		830	. .	.	. .	. .
Porter,	7	. .	67	4	871	. .	1	. .	9.57
Beer (ordinary),	5	.	70	3	. .	. .	1	. .	.15
" (light),	7	.	48	2	916	. .	1	. .	6.8

The Digestibility of Foods.—A knowledge of the digestibility of foods is of great importance. We live, not upon the food we eat, but upon what we digest and absorb. The following table gives the per cent. of the various foods usually digested by man:—

FOOD MATERIALS.	PER CENT. DIGESTED.		
	PROTEID.	FAT.	CARBOHYDRATE.
Meats and fish, ...	Practically all.	79 to 92	. . .
Eggs, ...	" "	96	. . .
Milk, ...	88 to 100.	93 to 98	. . .
Butter, ...	. .	98	. . .
Oleomargarine, ...	. . .	96	. . .
Wheat bread, ...	81 to 100.	. . .	99
Corn meal, ...	89	. . .	97
Rice, ...	84	. . .	99
Peas, ...	86	. . .	96
Potatoes, ...	74	. . .	92
Beets, ...	72	. . .	82

It will be noticed in this table that the proteids of milk are less completely digested than those of meats. Children, however, do better than adults in digesting the proteids of milk. We must, of course, in considering this question, neglect the idiosyncrasies of various people. What is digested by one is often difficult to digest by another. Diseases of the digestive canal frequently interfere with the digestion of food. Such variations from the normal cannot be taken into account in considering the digestibility of foods. In the table on pages 564 and 565 will be found the proximate composition of the ordinary articles of diet.

Circumstances that Affect the Digestibility of Foods —Source.—The proteids of animal origin are more easily and completely digested than those from the vegetable kingdom. The same may be said of fats. We know in regard to the carbohydrates that the starch from one plant is often more digestible than that from another. We know of no explanation for this. With regard to meat, some kinds of flesh are more easily digested than others by artificial gastric juice; thus, fish is more difficult to digest than meat; white flesh is more digestible than dark, raw beef than smoked.

Observations made in cases of gastric fistula, upon the time food stayed in the stomach, have shown that meat remains from two and one-half to five hours, the most digestible being lamb, beef, mutton, fish, veal, and pork, in the order named. Some starchy foods, as rice, barley, tapioca, remain two hours or less in the stomach, while others, such as beans, peas, potatoes, remain two and one-half hours; white bread three hours, and brown bread four hours.

Bulk or Volume of Food.—A bulky food throws excessive work on the stomach, causes discomfort, and all parts of the food cannot so well come in contact with the walls. The same amount of nutriment in small space is more easily digested. One objection to a vegetarian diet is in the fact that the N is so diluted by insoluble cellulose and unnecessary starch, that large volumes of food must be taken to obtain the requisite fifteen to eighteen grms. of N daily. The carbohydrates, too, are apt to undergo fermentative changes, and the gases so formed give rise to flatulence and discomfort.

The Reaction of Food.—As a rule, food should be slightly alkaline to excite a flow of gastric juice; too much alkali, however, neutralizes the gastric acidity and thus hinders digestion. Too much acid, such as lemon juice, vinegar, etc., may diminish digestion, and ultimately lead to serious disorders of the walls of the stomach.

Cooking of Food.—The cooking of food is not always a necessity, although it serves several useful purposes. It destroys parasites and the danger of infection. It breaks up the starch grains in vegetable foods, and makes them more easily affected by the digestive juices. It converts the insoluble collagen of animal foods into soluble gelatin, and disintegrates the connective tissue.

Of the two methods of cooking, roasting and boiling, the former is the most economical, as by its means the exterior is coated over with a coagulated coat which preserves the flavor and juices of the interior. Boiling renders the proteids more insoluble than they are in the raw state, but this is counterbalanced by the greater solubility of the connective tissue.

Artificial Digestion.—It is frequently found necessary with persons of feeble digestion to partially digest the food before it is administered. Artificial gastric juice, pancreatic juice, and juices of the pawpaw plant, and the pineapple, are employed for this purpose. The food to be digested is warmed to the temperature of about 40° C. (104° F.). The digestive agent is then added, and it is allowed to react for a time limited by circumstances. In such food we present to the enfeebled stomach, usually, half-digested foods. In the case of meats, the peptonization is seldom carried beyond the formation of albumose. It is the aim, usually, to prepare peptone, if at all, in very small quantities. The best commercial preparations called peptones, are chiefly albumoses containing but a small quantity of peptone. Indeed, the value of peptone as a food seems to be about the same as albumose. Artificially digested foods are usually bitter, if the digestion is carried too far. What this bitter substance is, is unknown. It is not albumose or peptone.

Absorption of Foods.—The absorption of the digested foods is more a physical and physiological process than a chemiical one. It is a process of osmosis, modified by special conditions. On one side of the mucous membrane of the intestines we have the blood and lymph, and, on the other, a concentrated solution of easily diffusible salts, peptones, dextrin, lævulose, soaps, and fat in a state of fine emulsion. The soluble carbohydrates, that is, dextrin, dextrose, lævulose, etc., absorb slowly, pass principally into the rootlets of the portal vein, and are carried to the liver, where a part is stored up as glycogen, the remainder disappearing.

The ultimate product of the hydrolysis of proteids, under the influence of pepsin and trypsin, and known as peptone, is the most diffusible proteid known. It is absorbed partly by the lymphatics, also somewhat by the blood-vessels, but is not found as peptone in the blood. If injected into the blood, it disappears inside of twenty minutes. If very large doses are injected, the animal suffers profound disturbances and usually death. Most of the peptone is reconverted into albumin while passing through the membrane Very little unchanged proteid is absorbed. Egg albumin, when mixed with a small quantity of sodium chloride, as well as myosin and alkali-albumin, is absorbed in small amounts The large intestine absorbs them more readily, the limit being 6 grms. of albumin or 50 grms. of egg white per day. The soluble soaps are easily absorbed. Very little of the fat undergoes saponification before absorption, but it is emulsified after a small amount of saponification. This emulsion is quite readily absorbed by the lacteals, and soaps can be detected in the portal blood, but rapidly disappear. No free fatty acids have been found in the blood. Alcohol, in part, at least, tartaric, malic, citric, and lactic acids, glycerin, inulin, and vegetable mucin are absorbed from the intestine; chlorophyll is not absorbed ; hematin only partly ; indigo, madder, alkanet, turmeric, and many other vegetable coloring matters are absorbed. The gums and pectin, not being peptonized, are not absorbed. Poisons are sometimes rapidly absorbed, and, at other times, slowly. Some organic poisons are stopped by the liver, while others are not.

Assimilation.—The function of food is to give heat and cell energy—mental, nervous, and muscular. The ultimate form in which food leaves the body is H_2O, CO_2, NH_3, uric acid, and urea. The intermediate forms and products, besides those of animal heat and motion, are as yet little known. Just what proportion of the food actually enters into the formation of the tissues before undergoing oxidation, and how much of it is oxidized merely to furnish heat, has been the subject of dispute, but the weight of evidence now seems to be that no proteid food is directly oxidized.

Liebig divided food into flesh formers and heat producers. The nitrogenous elements he termed the plastics, or flesh formers. We now know that they produce heat and fat as well as the carbohydrates. Formerly it was supposed that the blood was the seat of oxidation in the body, but now this view is abandoned. It is in the solid tissues where the principal oxidation takes place. While it is probable that most of the food becomes assimilated and takes the place of the tissues which are disintegrated, it is certain, however, that not all of the food taken enters into the composition of the tissues, or is assimilated. It is quite probable that a part of the glucose, at least, undergoes direct combustion during the circulation in the capillaries of muscular tissue during its contraction.

We have seen that the proteids are all absorbed as peptones, are converted into serin or serum-albumin and serum-globulin, during or immediately after absorption, and circulate in the blood and lymph in this form.

By slight modifications, which do not greatly modify their chemical composition, but rather their physical properties, they are converted into myosin, casein, ossein, gelatin, etc., to suit the needs of the different structures. These changes are due in many cases to loose combinations with various inorganic salts.

The carbohydrates, we have seen, are absorbed in the form of dextrose. It is also stated by some authorities that a small quantity of dextrin and cane sugar may be absorbed from the stomach, when they enter the venous circulation. It is more likely that dextrose, when taken with food, is absorbed here, as it is more diffusible than either of the others.

The dextrose which is absorbed from the intestines is changed by the liver into glycogen, although this substance is also prepared from the proteids of the blood. Glycogen is also found in many other tissues, as in the fœtal placenta, the skin, lungs, kidneys, muscles and epithelium. It is especially abundant in the muscles (0.4 to 0.8 per 100). It is augmented by a diet rich in starch, sugar, or dextrin. Dextrose is found in the muscle juice as well as in the blood.

The glycogen of the muscles accumulates during repose, but disappears during prolonged work, and may be one of the decomposition products of proteids.

The fats are absorbed principally as such, and are distributed throughout the body. The animal body also derives fat from the conversion of sugar or glycogen, and from the destruction of albuminoids.

The chemical processes involved in the appropriation of the various food substances we have been considering, are not thoroughly known. But by some sort of combination, the dead circulating proteid becomes a part of the living cell. The most important tissue of the body, because most abundant, is the muscular. Half the proteid material of the body and half the water exist in the muscles.

We can get some idea of the use of foods by feeding experiments upon animals, and strike a balance sheet between the whole of the matter taken into the body in a given time, including food, drink, and air, and the total excretions, including urine, fæces, perspiration, and breath.

The following table will illustrate what is meant by such a balance sheet:—

EXCHANGE OF MATERIAL ON ADEQUATE DIET. (*Ranke.*)

INCOME.			EXPENDITURE.		
FOOD.	NITROGEN.	CARBON.	EXCRETION.	NITROGEN.	CARBON.
Proteid, 100 grms., . .	15.5	53	Urea, 31.5 grms., . Uric acid, 0.5 grm.,	14.4	6.16
Fat, 100 grms., . . .	00	70			
Carbohydrate, 250 grms.,	00	93	Fæces, ...	1.1	10.84
			Respiration (CO_2), . .	0.	208.0
Totals, ...	15.5	225		15.5	225.00

Relation Between Proximate Principles of Food.—It has been found that the relation between carbon and nitrogen in our food should be 250 to 15, or 16.6 to 1. The proportion of these elements in proteids is 53 to 15, or 3.5 to 1. If a man should attempt to live upon lean meat, he must consume 2 to 3 kilos (5 to 6 lbs.) of beef to get the requisite amount of carbon. This quantity would contain more nitrogen than the body needs, and more than can be easily digested, or oxidized, if absorbed, and more than the kidneys can excrete. The overworking the kidneys would tend to produce chronic inflammation, and the accumulation of nitrogen would tend to produce gout and other troubles.

If the quantity of meat be adjusted for the proper amount of nitrogen, there would not be enough carbon to supply the waste, and the body would lose weight. A pure meat diet, therefore, cannot be maintained for a long time without serious injury.

The same thing is true, to a limited extent, with carbohydrates in the form of cereals, and especially in the flour made from them. By reference to the table on page 561 it will be seen that to get the requisite nitrogen in wheat bread 1.3 kilograms (2.8 lbs.) of it must be eaten, while less than half that amount would furnish the carbon.

In the practical construction of a diet, we first take enough meat to supply sufficient proteid, and then supplement this with sufficient carbohydrate and fat to furnish the necessary heat. The non-nitrogenous foods, *i. e.*, fats and carbohydrates, are thus termed **proteids-sparing foods.** The same term may be applied to gelatin, as this is its chief value as a food. The fats and carbohydrates, especially the latter, oxidize more readily than the proteids, and in this way protect the proteids, as well as the fat, from loss. The fats and carbohydrates seem to be able, to a certain extent, to replace each other without detriment. Fats and carbohydrates are both manufactured in the body from proteids, but this change is prevented by an abundance of the former. In diabetes mellitus, this conversion of proteids into dextrose is very great, and with consequent rapid loss of flesh and strength. Supplying carbohydrates does not then spare the proteids. Fats are formed in the body from the proteids of the tissues, as one of the retrograde or destructive changes. Hence it forms as a step in **degenerations of tissue.** Fats are also stored from the fat taken as food, or they are formed from carbohydrates

Food Accessories.—By food accessories are meant, those substances taken with food, such as alcohol, condiments, stimulants, etc.

Alcohol, when taken in moderate amounts, is burned in the body, and gives potential energy. One gram of alcohol in burning produces 7.054 calories, while dextrin, which occurs with alcohol in malt liquors, gives 4.117, and glucose 3.739. These substances are all capable of being used as combustibles.

While alcohol acts as a producer of force, it, at the same time, cannot be regarded as equal to the carbohydrates. Like them, it spares the nitrogenous waste, shown by its power of diminishing the excretion of urea In large quantities, however, it increases the excretion of urea, with the destruction of nitrogenous tissue. In this respect it behaves like certain active poisons, as arsenic and phosphorus. Like these poisons, it leaves a residue of fat after the decomposition of the tissues, and may lead to the accumulation of fat in certain organs.

There is another difference between the action of the carbohydrates and alcohol, and that is in the local irritant action of the latter on the stomach, other internal organs, and the central nervous system. While it serves to produce heat, spare the proteids, and stimulate the heart, it, at the same time, has a certain injurious action upon some of the tissues. Its paralyzing action upon the nervous system is shown by the dilatation of the capillaries, giving a sense of warmth in cold weather. This dilatation of the capillaries favors the loss of heat by radiation and the lowering of the general temperature. The larger the dose the greater its paralyzing effect upon the nerves controlling the capillary circulation, and the greater the elimination of heat. The effect of a small amount of alcohol well diluted, upon digestion, is to assist it. The continued use of the stronger solutions (whiskey, brandy, gin, etc.) produces a catarrhal inflammation, and when used in excess, acute gastritis. The appetite very often either fails entirely, or is singularly modified to crave meats only, as a diet. This leads to the over-production of urea and uric acid, with gout, rheumatism, cystitis, or nephritis. Statistics based upon observations made upon thousands of men put under the same conditions, as in armies, have shown that "soldiers, in war or peace, in all climates, in excessive heat or cold, in rain and the hardships of the severest marches, endure best when all alcoholic drinks are withheld." (A. Baer.)

We must, therefore, regard alcohol as an expensive food, with certain good results when taken in reasonably small amount and well diluted, as in claret and beer, but when taken in larger quantity, it acts as a poison which interferes with the normal metabolism, increasing nitrogen waste, and perverting the function of digestion, the nervous system, and some glandular organs. In this last case, the net result of its action in the body is injurious. It has been estimated that the human body can burn about two fluid ounces of absolute alcohol per day. This will represent about 4 to 5 ozs. of whiskey or brandy, 10 ozs. of sherry or port wine, 20 ozs. of claret, champagne, porter, or Bass's ale, or 40 to 60 ozs. of American beers.

Tea, coffee, maté, and cocoa are used principally as nerve stimulants. The first three owe their stimulant properties to caffeine (tri-methyl-xanthin); cocoa to the related alkaloid theobromine (dimethyl-xanthin). It is noteworthy that all people in all climates make use of some plant that contains these or similar alkaloids. The most of the caffeine so taken is destroyed, but when the amount taken reaches 0.5 grm. (8 grs.) a portion of it passes into the urine.

A cup of coffee, according to Bunge, contains about 0.1 grm. caffeine, and about the same amount is contained in from 2 to 10 grms. of dry tea leaves. Coffee has little influence upon the excretion of urea and does not, therefore, act injuriously unless taken in doses sufficient to over-stimulate the nervous system. It does, however, sometimes act injuriously upon stomach digestion. The same may be said of tea and cocoa. Chocolate is not only a stimulant, but a rich food. It contains about half its weight of fat, and, besides, about 12 per cent. of nitrogenous matter. It is, therefore, a concentrated food.

Beef Tea and **Beef Extracts** owe their value to the extractives which are stimulants and proteid savers. Some have regarded the inorganic salts as having a large share in their refreshing effects. They have little if any food value. The gelatin contained in soups and beef tea saves the waste of nitrogenous tissue during fever, and thus retards the loss of strength, but does not add to the construction of tissue or blood. Liebig's extract and similar preparations owe their effects principally to the extractives, creatin, xanthin, hypoxanthin, carnin, lactic acid, and inorganic salts. They contain about 78 per cent. of solid matter, of which about 60 per cent. consists of organic matters, principally composed of these extractives, and 18 per cent. of salts.

Condiments, such as pepper and other spices, are useful only as means of whetting the appetite. They probably act by mildly irritating the mucous membranes, causing an increased flow of the digestive juices.

The Source of Muscular Energy.—We have heretofore spoken of the oxidation or burning of the food in the body, as the source of all heat, muscular power, and nervous energy. We have also seen that the food does not burn as such, but it supplies the place of tissue that has burned, and thus maintains the equilibrium. When the body neither loses nor gains weight; there is just as much food material converted into tissue as there is tissue destroyed.

The action of the food may be roughly illustrated by a tube open at both ends and filled with marbles. If we push a marble in at one end, one is pushed out at the other. If two or three are put in, two or three are pushed out. The marbles that are pushed out are equal in number, kind, and weight to those pushed in, but are not the same marbles. So the food enters the tissues on one side and crowds out waste products on the other. When more food is taken, more waste is crowded out and excreted.

The changes that are observed when a muscle contracts, are at first, an elevation of temperature, an increase in the circulation in the muscle brought about by a dilatation of the capillaries, and acid reaction from sarcolactic acid. The elevation of temperature is nearly proportional to the energy of the contraction, or the work done by the muscle.

It has been demonstrated that the muscle glycogen diminishes rapidly during the contractions, and gradually accumulates when the muscle is in repose; also that the glucose disappears from the blood flowing through a muscle when at work. Chauveau showed by analysis of the blood entering and leaving the masseter muscle of a horse: First. That the amount of blood traversing a muscle is 2.5 to 3 times more during work than during repose.

Second. The oxygen consumed by 1000 grms. of muscle, and the CO_2 formed are 3½ times as much during work as during repose.

Third. That the glucose which disappears from the blood and passes through the muscle in a half hour, is 3½ times as much during work as during the same time in repose.

At the same time the glycogen largely disappears from the muscle.

The greater part of the real energy of a muscle comes from the oxidation of glucose, or glycogen.

A part of these bodies is changed into lactic acid, and a small amount of nitrogenous waste takes place, with the formation of fat, creatin and other lucomains which accumulate in the muscle.

It has not been demonstrated that urea or uric acid are much increased by muscular work, but the myosin and globulin seem to slightly diminish, and are probably converted into creatin, fat, etc. This explains why the urea excreted is not in proportion to the work performed by a man. The accumulation of leucomains, and the exhaustion of glycogen are the causes of fatigue.

It has been shown that a laborer who works ten hours a day must have, to keep his body in a good state of health, over and above that necessary for a state of idleness, the following amounts of nourishment (Gautier):—

42	grms.	of albuminoids,	giving	163	calories	of heat.
12	"	" fat,	"	102	"	"
160	"	" carbohydrates,	"	693	"	"
			Total,	958	"	"

From this it follows that 81 per cent. of the work done by the laborer comes from the burning of the fats and carbohydrates, and 19 per cent. from the albuminoids, which latter must be replaced molecule for molecule, by food.

The 42 grms. of albuminoids consumed ought to produce 14 grms. of urea if entirely consumed and excreted in this form. In fact, only about one-sixth of this amount is obtained. There is, then, but a very small increase in urea excreted during work, over that excreted in idleness. Fick has demonstrated that about 33 or 34 per cent. of the total intramuscular combustion appears in the form of muscular work, while the remainder is thrown off as heat. This, indeed, is the principal source of animal heat. Helmholtz estimates that of the total heat produced by oxidation in the body, about 7 per cent. is represented by mechanical work, and 74 per cent. is radiated and evaporated by the skin, and the remaining 19 per cent. by the lungs, urine, and fæces.

DIGESTION.

Digestion has for its object the preparation of food for the nourishment of the tissues. There is an external and an interstitial digestion. External digestion is the preparation of the food for absorption; interstitial digestion is the more hidden process by which the food in the interior of plants and animals is modified and made available for nutrition. External digestion is illustrated by the manner in which certain lower animals take their food, as, for example, the Amœba, which rolls itself about its food, extracts the nutriment, and unrolls to allow the debris to escape. In the Venus fly-trap we have an example of the same process in plants. The alimentary canal is a prolongation of the skin, and may therefore be considered as being outside of the body.

Reserves of food are such portions as are stored up in the bodies of plants and animals for future use, such as fat and glycogen in animals, and starch and sugar in plants.

Digestion is carried on by means of soluble ferments or enzymes. The number of ferments employed in the digestion of the food used by man is not accurately known. There are at least seven or eight of them. The following table presents these ferments, with their origin and the changes which they produce:—

TABLE OF THE DIGESTIVE JUICES AND THEIR FERMENTS.

DIGESTIVE JUICE.	FERMENTS CONTAINED IN THEM.	ACTION ON FOOD MATERIALS.
Saliva.	Salivary diastase or ptyalin.	Changes starch into dextrin and maltose.
Gastric juice.	*a.* Pepsin.	Changes proteids into peptones in an acid medium.
	b. Curdling ferment.	Curdles the casein of milk.
Pancreatic juice.	*a.* Trypsin.	Changes proteids into peptones in alkaline and neutral media.
	b. Curdling ferment.	Curdles the casein of milk.
	c. Pancreatic diastase.	Changes starch into dextrin and sugar.
	d. Emulsive ferment.	Emulsifies and partially saponifies fats.
Bile.	?	Assists in emulsifying fats.
Intestinal juice.	*a.* Invertin.	Changes cane sugar into invert sugar.
	b. ? Curdling ferment.	Curdles the casein of milk.

The Saliva.—The first fluid to which aliments are subjected is the saliva. The saliva is the combined secretion of the parotid, submaxillary, and sublingual glands, mixed together, with mucus from the mucous membrane of the mouth. It is a slightly turbid, viscid, frothy fluid, without taste or odor, slightly alkaline in reaction, and of a sp. gr. from 1002 to 1008. It contains about .5 per cent. of solids, of which .2 per cent. is salts, and the rest ptyalin, globulin, serum albumin, mucin, and salivary corpuscles.

MIXED SALIVA—HUMAN.

	(JACUBOWITSCH.) PER CENT.	(HAMMERBACHER.) PER CENT.
Water,	99.51	92.42
Solids,	0.48	0.58
Soluble organic bodies (ptyalin, etc),	0.13	0.14
Epithelium,	0.16	0.22
Inorganic salts,	0.182	0.22
Potassic sulphocyanate,	0.006	0.004
Potassic and sodic chlorides,	0.084	. . .

The alkaline reaction is due to the presence of bicarbonates and alkaline phosphates. The alkalinity differs in different individuals, and in the same individual at different times in the day, and may become neutral or acid without disturbance of the health, especially between the meals. Pathologically, it may become more alkaline, or even decidedly acid. The salts present are $HNaCO_3$, KCl, NaCl, KCyS, Na_3PO_4, the sulphates and phosphates of calcium and magnesium, ammonium nitrate, and sometimes urea. It contains free O, N, and CO_2 in solution. It is richer in CO_2 than blood. On exposure to the air, the CO_2 escapes, when some of the salts of calcium and magnesium are precipitated, accumulate on the teeth, and give rise to the deposit known as "tartar."

The parotid secretion is clear and watery, rich in ptyalin and poor in mucin. The sublingual is richest in ptyalin, is strongly alkaline, is viscid, and traces of cholesterin and fat have been found in it. The submaxillary is more alkaline than the parotid, is rich in corpuscles and mucus, but poor in ptyalin. The saliva is increased by the stimulation of certain nerves, or by the irritation of pepper, alkalies, and food, or even the thought of food. The saliva of irritation is alkaline and contains little or no ptyalin. It is increased by pilocarpine and eserine, but diminished by atropine. In the saliva of the new-born, only that secreted by the parotid contains ptyalin, while it appears in the submaxillary after about two months.

Uses.—The saliva moistens and lubricates the food and converts starch and glycogen into soluble starch, dextrin and maltose. The saliva acts best in a neutral or faintly acid solution, if the acidity be due to organic acids. It does not act in the presence of free HCl, or HCl and pepsin. Its activity is increased by small quantities of NaCl, Na_2SO_4(.4 per cent), NH_4Cl, CO_2, acetate of quinine, strychnine, and morphine. Tea has an intense inhibitory effect, coffee and cocoa very little effect. The saliva becomes more alkaline in very acid conditions of the gastric juice, and even more abundant, giving the disease known as pyrosis, or water-brash. The saliva acts very feebly on uncooked starch. A peptone-forming ferment has been found in the saliva.

Gastric Juice.—The gastric juice is a thin, transparent, faintly yellow, acid fluid, of sp. gr. 1001 to 1010. It contains from .5 to 1 per cent. of solids, of which ⅔ or less is organic matter. The pyloric end of the stomach gives the alkaline fluid, or **succus pyloricus,** which is said to convert starch into sugar, and to digest albumin when acidified with HCl, and to dissolve gelatin. The thick, slimy secretion of the stomach, in a state of rest, is neutral or alkaline. The normal secretion of the stomach is a mixture of these fluids. The daily quantity of the gastric juice is variously stated at from 16 to 31 pounds, or about 20 pints. Its composition is as follows:—

ANALYSIS OF GASTRIC JUICE (HUMAN) MIXED WITH SOME SALIVA.

(*After C. Schmidt.*)

	PER CENT
Water,	99.44
Solids,	0.56
Organic substances (pepsin and peptones),	0.32
Free hydrochloric acid,	0.25
Sodic chloride,	0.14
Potassic chloride,	0.05
Calcic chloride,	0.006
Phosphates of lime, magnesia, and iron,	0.015

The acidity of the gastric juice of some of the lower animals, especially the dog, is greater than that in man. In the dog it is nearly six times that of man; in the fish it may even be seven times as much as that of man. The organic matter present is chiefly pepsin and a little mucin, and amounts to about .3 per cent. The acidity of the gastric juice is made up of hydrochloric and organic acids. The organic acids are chiefly lactic and butyric, with occasionally acetic. These are not secreted in the gastric juice itself, but are produced partly by the decomposition of their salts in the foods taken, and partly by fermentative action; so that in the earlier stages of digestion the acidity is chiefly due to organic acids, but, in the later stages of digestion, chiefly to hydrochloric acid, which is present in quantities varying from .1 to .4 per cent.

The hydrochloric acid is greatly diminished or entirely absent in the acute fevers during the fever, in chronic gastric catarrh with atrophy of the gastric glands, amyloid degeneration of the membrane, in all cachectic states, chlorosis, certain nervous troubles, many forms of poisoning, Addison's disease, cancer of the stomach, if it involves a considerable area, or is attended with catarrh of the mucous membrane, which is usually the case. It is absent, as a rule, in cancer of the stomach, and this fact is a valuable aid in the early diagnosis of this disease.

The HCl is probably produced by one of the following reactions:—

$$(1.)\ 2Na_2HPO_4 + 3CaCl_2 = Ca_3(PO_4)_2 + 2HCl + 4NaCl.$$

$$(2.)\ CO_2 + 2NaCl + H_2O = Na_2CO_3 + 2HCl.$$

$$(3.)\ \underset{\text{Acid sodium carbonate.}}{NaHCO_3} + \underset{\text{Sodium chloride.}}{NaCl} = Na_2CO_3 + HCl.$$

Others think that the HCl in the gastric juice is in combination with some of the amid bodies, as leucin or tyrosin, which are found in all glands. Liebermann claims that there exists an acid reacting compound of lecithin and albumin, always found in the mucous membrane of the stomach, which takes up the Na_2CO_3, the second, or the $NaHCO_3$ of the third reaction. The compound thus formed gradually sets free the Na_2CO_3, which passes into the blood. Besides HCl and the organic acids above spoken of, the gastric juice contains ferments, two of which are of special interest, namely, pepsin and rennin or labferment. There exist also in the stomach at times, certain gases, especially CO_2, O, N, H, and CH_4. It is evident that these gases are the result of the microbial fermentation of aliments.

Action of the Gastric Juice.—The gastric juice acts especially upon the proteids. It modifies them by transforming them successively into syntonin, or acid albumin, then into propeptones or albumoses, and finally into peptones. These compounds have already been described. It is evident from what has just been said, that during digestion a part of the HCl only, is in the free state, while a part of it is in combination with albumin, in the state of acid albumin.

The phenomena of gastric digestion are due to the hydration of the albumin, and a breaking up of molecules into simpler ones, so that the peptones are richer in H and O than the albuminoid bodies from which they were produced.

Chemical Examination of the Gastric Juice.—The chemical examination of the contents of the stomach has, in recent times, become an important aid in the diagnosis of diseases of the stomach. This generally includes an examination as to the rapidity of absorption, the motility, the reaction and acidity of the gastric juice, the determination of the kind and amount of acids present, an examination for syntonin and peptone, and the determination of the digestive activity. The juice for examination is obtained as follows: The usual method is to administer to the patient, on an empty stomach, an ordinary dry roll and a definite quantity, say 300 c. c., or about ⅔ pint, of fluid, either simple warm water or weak tea without milk or sugar. The roll should be of a tolerably uniform weight of about 35 grms., or 540 grs. Such rolls contain about 7 per cent. of N, .5 per cent. of fat, .4 per cent. of sugar, 52.5 per cent of non-nitrogenous matter, and about 1 per cent. of ash. This **test-breakfast** contains chiefly albuminoids, sugars, starch, non-nitrogenous extractives, and salts. By means of this breakfast the stomach is given all the ingredients usually taken, with the advantage that they are liquefied in a relatively short period of time, or at least sufficiently liquefied to be capable of being easily drawn off through a tube. About one hour after taking the test-breakfast, the stomach tube is inserted, and that which remains in the stomach is drawn off. The amount obtained should be about 40 c. c., or 1⅓ ozs. A greater variation than 15 to 20 c.c. in either direction should be regarded as pathological. The fluid thus obtained is filtered as soon as possible, and the tests are applied to the clear filtrate.

The Acidity.—The acidity of the gastric juice is due to HCl, lactic acid, acid salts, and, occasionally, butyric or acetic acids. In the clinical examination, it is important to determine the cause of the acidity, as well as its amount. For this purpose various anilin dyes are found to be useful. Of these the best are **Congo red** and **tropæolin** OO. Tropæolin is, when dry, an orange-colored powder, and in a saturated watery or alcoholic solution forms a dark yellow-red solution, which, in the presence of free acids, changes to reddish-brown, but with acid salts straw yellow. Even as little as .25 per 1000, or 1 in 4000, of free acid can be detected by this reagent. Congo red is also a sensitive reagent for the detection of acids. The solution is of a deep wine-red color, which changes to a sky-blue with acids. It is more delicate than tropæolin, and will react to a fluid containing but .02 per 1000. Acid salts produce no change. **Benzo-purpurin** is another color which has been used. It is also a deep red color, which changes with acids to a deep blackish-blue color. If more than .4 per cent. HCl be present, the color produced is brown-black. If this color be employed in the form of test-paper previously prepared by dipping unsized paper in the solution and drying, we may distinguish between organic and inorganic acids by placing a strip of paper which has been changed in color by the gastric contents, in a test-tube with ether. As the organic acids are soluble in ether, they dissolve out of the paper, and the color produced by them will disappear, while if the color is produced by HCl, it will remain unaltered. Many prefer to use all these colors in the form of test-papers prepared as above described. A considerable number of other colors have been recommended for the clinical testing of the gastric contents, but the ones here mentioned are those most generally useful. The most delicate test for free hydrochloric acid is that known as the **Gunzburg's test.** The solution is made as follows:—

Phloroglucin, ...	2 grms. (30 grs.)
Vanillin, ...	1 grm. (15 grs.)
Absolute alcohol, ...	30 grms. (1 fl. oz.)

This solution is pale yellow in color and has the odor of vanilla. It should be kept in blue or black bottles. It is employed as follows: A few drops are spread out in a thin layer upon a porcelain dish or slab, which is then gently heated and a drop of the solution to be tested is allowed to flow across it, or a glass rod dipped in the solution is drawn across the plate. If free hydrochloric acid be present, a deep scarlet-red streak is developed. If the acid be very weak, no change is observed until the solution evaporates entirely to dryness; blowing on the dish will cause the red streak to appear more rapidly. With this test it is unnecessary even to filter the gastric contents. This test is not simulated by the albuminoids, nor is it interfered with by acid salts, if present in the usual proportions, nor by organic acids. Its delicacy is such that it shows one part of HCl in 20,000 parts of water. Tropæolin paper fails when the HCl falls below one part in 3500. The reagent of Boas seems almost as delicate as Gunzburg's. It is prepared as follows:—

Resorcin, pure, ...	5 grms.
White sugar, ...	3 grms.
Diluted Alcohol, ...	100 grms.

This reagent is employed in the same manner, and the indication is similar to that above described for Gunzburg's reagent. The red color produced with it is positive proof of HCl, and is never produced by organic acids.

Detection of the Organic Acids.—There are two lactic acids met with in the stomach, sarco-lactic acid and fermentation lactic acid. Sarco-lactic acid is formed in the stomach from meat taken as food; the other lactic acid may be formed by fermentation. A very simple and rapid test for clinical practice is that of Uffelmann. Diluted solutions of ferric chloride turn canary yellow in the presence of lactic acid. A still better solution is the following: A few drops of a diluted neutral solution of ferric chloride are mixed with two drops of pure carbolic acid, and water added until the solution assumes a beautiful amethyst blue color. A few drops of a 1 in 2000 solution of lactic acid changes the color to yellow instantly. The delicacy of the reaction is very great. Lactates, as well as free lactic acid, unfortunately, produce this yellow color. It is said that alcohol, sugar, and certain salts can produce the same color. The test becomes certain if we first extract the organic acid from the gastric contents with ether, and apply the test to the residue left on evaporating off the ether. Acetic and butyric acids can usually be detected by the odor. The odor of acetic acid is usually unmistakable. It may also be detected by the use of ferric chloride, with which it gives a red color. Butyric acid changes Uffelmann's reagent to a tawny reddish color, and this only occurs when it is present in over 5 parts per 1000. Alcohol is found only in rare cases of yeast fermentation.

The quantitative estimation of the total acidity is best done by trituration with a decinormal alkali. Ten c. c. of the clear filtered liquid is diluted with 30 or 40 c. c. of water, a few drops of an alcoholic solution of phenol phthalein or litmus solution are added, and the decinormal NaOH solution is run in from a burette (see Fig. 68) until a change of color is produced. As 1 c. c. of the decinormal alkali neutralizes 0 003637 grms. of HCl, and as we usually express the acidity in its equivalent in this acid, the number of c. c. of alkali used multiplied by this factor gives the amount of HCl, or its equivalent. in the 10 c. c. used. Thus if 6 c. c. alkali were used, the acidity will be 6 × .003637 = .021822 grm. in 10 grms. of liquid, or 0.218 per cent.

The total acidity of the gastric juice is made up of HCl, organic acids, and acid salts. As the organic acids are soluble in ether, they may be dissolved out before trituration, by shaking 10 c. c. of the liquid with 100 c. c. of ether. The acidity of the liquid then represents HCl and the acid salts. It is necessary also to distinguish the free acid from the HCl combined with the proteid as acid albumin. There may be an abundance of HCl in the liquid, with but a slight acidity, because most of the acid has combined with the proteids.

The **free acids** may be estimated by the titration of 10 c.c. of the fluid after treatment with 1 grm. of precipitated and thoroughly washed $CaCO_3$. The free acids decompose $CaCO_3$, while the acid salts do not. The acidity of the filtrate, after treatment with the precipitated chalk, gives that due to acid salts, which, deducted from the total acidity, gives the free acids. A **simple and easy method** of estimating the free HCl is to dilute the filtered fluid, that has given a positive reaction with Günzburg's test, to $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{10}$, etc., unil the test fails with the diluted solution. Since we know the limit of reaction to be 1 in 20,000 (0.005 per 100), we can tell the amount of HCl present. Thus, if the red color fails with dilutions weaker than the $\frac{1}{20}$, this will contain 0.005 × 20 = 0.1 per 100 or 0.1 per cent.

Ethyl green, or methyl violet, may be employed in the same manner. The first is said to be about as delicate as Günzburg's test, when the solution of the color used is dilute.

Another method for obtaining the free HCl is as follows: If a mixture of organic acids and free or loosely combined HCl be treated with $BaCO_3$, evaporated to dryness, and reduced to ash, all the chlorine combines with the Ba as $BaCl_2$, which is soluble in water. The organic barium salts are decomposed during the ignition and do not go into solution, but remain as $BaCO_3$. This solution is filtered and treated with Na_2CO_3, which precipitates the Ba as $BaCO_3$. This is filtered out and again dissolved in HCl. The excess of HCl is removed by evaporating to dryness, and the dry residue again dissolved in water, when the chlorine is estimated with decinormal silver nitrate, using potassium chromate as an indicator. One c.c. of the decinormal silver solution corresponds to 0.003637 grms. of HCl, from which the amount of HCl in the gastric juice taken may be calculated. For clinical purposes it is unnecessary to employ this somewhat complicated process.

Hydrochloric acid may appear free in the contents of the stomach, it may occur combined loosely with the proteids, or it may occur as chlorides of inorganic bases. It is generally considered important to estimate the free acid as well as that combined with the proteids. To estimate the free HCl, 10 c. c. of the filtered stomach contents are taken and titrated with a decinormal soda solution, added from a burette, until Günzburg's reaction no longer occurs. The alkali added corresponds to the amount of HCl present. For example: If 10 c. c. of gastric juice no longer react with Günzburg's reagent, after adding 1.3 c. c. decinormal soda solution, then the amount of free HCl is 1.3 times .003637 = .047 per cent. HCl. The loosely combined HCl may be estimated by continuing the above trituration, drop by drop, after the failure of Günzburg's reaction, with congo-red paper as an indicator.

Estimation of Free HCl, Organic Acids, Acid Salts, and Loosely Combined HCl, in the Same Solution.—Ten c. c. of the filtered fluid, which has reacted positive with Günzburg's test, are measured out, and $\frac{N}{10}$ NaOH added, a few drops at a time, until a drop of the solution fails to give Günzburg's test. The reaction is now tested with a piece of Congo paper. If it shows no acid reaction, less than 0.02 per cent of lactic or other organic acid is present. If the paper turns blue or lilac, continue to add the alkali solution until the red color of the paper is restored.

The quantity of NaOH solution required after the failure of the Günzburg test, to the changing of the Congo paper, gives the organic acids. Butyric and acetic acids would have been detected by the odor.

[illegible] may be estimated as lactic acid, but it is usu- [illegible] as [illegible] the number of c. c. of NaOH [illegible] in the gastric contents. Thus [illegible] we may say the lactic acid is [illegible] represented by 10 c. c. of NaOH [illegible]

[illegible] end reaction with Congo paper, a few [illegible] may be added, and then enough alkali [illegible] The amount of alkali now added [illegible] with albumin plus the acid salts. The [illegible] from the beginning gives the total acidity [illegible] we determine the free HCl, the free [illegible] and the loosely combined HCl and the acid salts. [illegible] gives a negative test after Günzburg's [illegible] free HCl there are no free organic acids [illegible] should show a negative test with [illegible] reagent the titration is begun upon [illegible] This is continued until [illegible] and the quantity used [illegible] If a positive test is [illegible] If negative, more HCl [illegible] The number of c. c. of deci- [illegible] the [illegible] reaction with Congo is [illegible] with Günzburg's reagent, wil- [illegible]

[illegible] is detected by Uffel- [illegible] obtained one hour after [illegible] carried out in every [illegible] the average amount of HCl [illegible] digestion, we are able to [illegible] variations from the normal [illegible] free HCl should require from 40 to [illegible] NaOH [illegible] 100 c. c. of the fluid [illegible] not require more than 75 to 80 c. c. [illegible]

[illegible] of Acid Albumin, Albumose and Peptone. [illegible] test. The filtered fluid [illegible] with NaOH or KOH and a few drops [illegible] A red or violet color indicates [illegible] The presence of peptone [illegible] the presence of digestive power in the [illegible] or acid albumin, may be detected by simple neutralization of the filtrate, when it is precipitated. Albumose may be shown to be present if the filtrate from the precipitate of syntonin, or the liquid in the absence of syntonin, is saturated with ammonium sulphate. Albumose is precipitated as a white cloud, soluble on warming. The filtrate from the precipitation of the albumose may be tested for peptone by the biuret test, or by the addition of picric acid solution, which precipitates peptone.

The Ferments, Pepsin.—The test for pepsin is accomplished by the addition of coagulated egg albumin to the filtered gastric contents, and keeping this mixture at a temperature of about 40° C. (104° F.) for a definite time, and noting whether the albumin is corroded. If the gastric contents have been found by the above test to be destitute of sufficient HCl, enough should be added to bring the quantity up to about 2 parts per thousand. Coagulated albumin discs, made by cutting the white of boiled eggs in thin flakes of uniform thickness, and punching out by means of a cork borer or glass tube, and preserved in glycerin, are best used for this purpose.

The presence of **rennin** is best shown by carefully neutralizing 5 c.c. of the filtered gastric contents, and mixing this solution with an equal volume of carefully neutralized milk. If rennin be present, the milk is coagulated in a few minutes.

Rapidity of Absorption from the Stomach is tested by giving the person a capsule containing 0.1 grm. of potassium iodide and then testing the saliva for the iodine reaction. **With a normal stomach, iodine appears in the saliva 10 to 15 minutes after giving the capsule.**

The iodine is detected in the saliva as follows: Strips of filter paper are soaked in starch mucilage and dried. One of these papers is pressed upon the tongue, removed, and then touched with a glass rod previously dipped in some yellow nitric (nitrous) acid The appearance of a blue spot shows the presence of iodine.

The Motility or **Motor Function** of the stomach is a matter of importance, and its determination is sometimes required. When the motility is normal or increased, the food, even if it is not digested, is passed on into the duodenum before any disturbance arises from lack of digestion. The motor function may in this way compensate for lack of digestive power in the stomach. The lack of proper motor power, on the other hand, may produce dyspeptic symptoms where the digestive power is normal, because of the long delay of the food in the stomach, with secondary fermentations.

Ewald's Salol Test is the best test of the motility of the stomach. It does not decompose until it reaches the duodenum, when it forms phenol and salicylic acid, which latter is then absorbed and appears in the urine from 60 to 75 minutes after taking about 0.6 to 1 grm. in a capsule. Or, we may note how long the salicylic acid continues to be eliminated by the urine. If the reaction shows the acid in the urine at 30 hours or longer, it may be regarded as proof of deficient motility of the stomach. Salicylic acid is easily detected in the urine, by wetting a piece of filter paper with this fluid, and dropping on the moistened spot a drop of a 10 per cent solution of ferric chloride. The edge of the drop will assume a violet color in presence of traces of salicylic acid. These papers may be dried and preserved, if necessary, as records of the test.

Klemperer pours 100 c.c. (3⅓ ozs.) of pure olive oil into the empty stomach, and removes with the stomach tube what remains after two hours, to determine how much has been passed into the duodenum.

The Pancreatic Fluid.—The pancreatic fluid is the secretion of the pancreas, poured out into the duodenum at the junction of the middle and lower third of the duodenum through the pancreatic duct. In some lower animals there are two ducts. The rabbit, dog, and cat, each have two ducts. The pancreatic juice is a transparent, colorless, odorless, saltish, alkaline fluid, effervescing witn the acids. It is composed of water 90 per cent. and of solids 9.93 per cent. There are few cells, if any, in its solution, and it is, therefore, clear. The pancreatic fluid has at least three ferments, or zymogens that furnish at least three ferments; the diastasic ferment, **amylopsin,** allied to if not identical with ptyalin, **trypsin,** a peptone-forming ferment, and **pyalin,** a saponifying ferment.

The secretion of the pancreatic juice begins as soon as food is taken, increases for two hours, then falls, and a second rise takes place in from 5 to 6 hours, when it falls again to 0 in about 18 hours, if no more food be taken. The most marked characteristic of the pancreatic secretion is that it acts in neutral or alkaline solutions rather better than in acid solutions. A slight excess of HCl destroys it entirely. Its most marked action is upon proteids and starches, converting the former into peptone with certain side products, and the latter into maltose, which is afterward rapidly changed into glucose. Pancreatic digestion differs from peptic digestion in certain well-marked features which are shown below:—

Active Pepsin.—Acid Medium.	Pancreatin.—Alkaline Medium.
Fibrin swells before dissolving.	Fibrin corroded away.
Assisted by HCl.	Assisted by Na_2CO_3.
Destroyed by Na_2CO_3.	Destroyed by HCl.
Forms syntonin, albumose, and peptones.	Forms alkali albumin, antipeptone, hemipeptone, leucin, tyrosin, hypoxanthin, and aspartic acid.
Acts best on albumin.	Acts best on fibrin.

The pancreatic fluid is the chief digestive fluid concerned in the complete digestion of starch. It contains the ferment **amylopsin,** or **pancreatic diastase,** which readily converts starch into maltose and finally into glucose. The extract of the pancreatic gland is exceedingly active in its effect upon cooked starch. This secretion in the new-born is destitute of amylopsin, which makes its first appearance at about the end of the second month. Previous to this time, infants cannot usually digest starch. Some infants, however, seem to be endowed with the property of digesting starch, and it would seem, therefore, that they must secrete some diastase, either in the saliva or the pancreatic fluid. The milk-curdling property of the pancreatic fluid is less marked than in the case of the gastric fluid. Of the fat-splitting ferment little is known, except that a special ferment exists in the pancreatic juice which has this property. It decomposes lecithin into neurin, and saponifies fats to a slight extent only, but sufficiently to assist in the formation of a perfect emulsion. A small amount of free acid in the oil greatly assists its emulsification with a diluted solution of sodium carbonate. For this reason a slightly rancid oil emulsifies more readily than a neutral oil.

The Succus Entericus is the digestive fluid secreted by the mucous glands of the intestinal mucous membrane, principally by Lieberkuhn's and Brunner's glands. The secretion from Brunner's glands contains proteids, mucin, and ferments. It dissolves proteids, slowly changes starch into sugar, changes maltose into glucose, and inverts cane sugar. It is a light yellow, opalescent, strongly alkaline fluid. The succus entericus is most active in the dog. Its diastasic power is less than that of the saliva or the pancreatic fluid, and when it acts upon starch it forms glucose instead of maltose. The large intestine contains none of this ferment.

The Bile.—The bile is a viscid, transparent, golden-yellow colored liquid secreted by the liver. It has a bitter taste and alkaline reaction. Specific gravity, 1009 to 1020. Its composition is highly complex, but is represented principally by the following:—

	Per Cent.		Per Cent.
Water,	91.68	Soaps,	1.39
Mucus and pigment,	.129	Fat,	.73
Glycocholate of sodium,	3.03	Lecithin,	.53
Taurocholate of sodium,	0.87	Cholesterin,	.35

The amount of bile secreted in 24 hours is variously stated at from 1000 to 1700 grms , or from 23 to 47 ozs. The bile is prepared in the liver from the large amount of blood received by it. More is secreted during digestion than during fasting, and the per cent. of solids increases during digestion. In abstinence from food, or with a fatty diet, little is secreted; more is secreted with bread and rice, still more with meat, but most with a mixed diet. The bile is stored in the gall bladder when not needed, and poured into the duodenum near the point of exit of the pancreatic duct. On standing, the bile becomes of a brown-yellow color and readily undergoes decomposition.

The constituents of the bile are described elsewhere.

The functions of the bile are:

First. To assist in emulsifying fats, and, in the presence of the pancreatic juice, it assists in saponifying a small portion.

Second. It readily wets the mucous membrane, dissolves fats, and it assists in their absorption.

Third. Checks putrid fermentation in the intestines.

Fourth. It precipitates the pepsin, syntonin, albumoses, and peptones from the chyme, and stimulates the production of intestinal juice.

Fifth. It contains a diastasic ferment which converts starch into sugar.

Sixth. The bile stimulates the contractions in the muscular coat of the intestines and villi, increases the moisture in the intestine, acts as a lubricant, and favors the passage of the contents of the small intestine.

A considerable portion of the bile is re-absorbed; a part of the coloring matter at least being excreted by the kidneys, while a part passes out with the fæces. The biliary acids are mostly absorbed from the ilium and jejunum, only a trace being found in the fæces.

Toxic Effects.—Obstruction to the discharge of the bile leads to its absorption by the lymphatics, giving rise to cholæmia, or absorptive jaundice. The coloring matter passes into the circulation and stains the tissues yellow. The effect upon the heart is to produce a slow pulse and respiration, low temperature, irritation of the skin, lassitude, headache, and coma.

THE FÆCES.

Chemical Composition of Fæces.—An adult, upon a mixed diet, passes about 120 to 150 grms. of moist excrement in twenty-four hours. A vegetable diet increases the weight. If much indigestible food be taken, it may be as much as 500 grms. The consistency depends upon the amount of water present, which is usually about 75 per cent. A pure flesh diet gives a comparatively dry fæces, while substances rich in sugar yield fæces with a comparatively large amount of water. The quantity of water taken has no influence upon that found in the fæces. The water in the fæces seems to be in direct ratio with the energy of the peristalsis. The fæces have a neutral, sometimes alkaline, and rarely acid, reaction. The alkalinity is derived from the ammoniacal fermentations, while the acidity is from the lactic and butyric acid fermentations. Acetic and propionic acids have also been found in the fæces. The copious secretion of mucus favors the occurrence of the neutral or alkaline reaction.

The color depends upon the amount of altered bile pigment mixed with them, to which the bright yellow to dark-brown color is due. The color of the food is sometimes imparted to the fæces. If much blood be present, that is, after hemorrhages, the fæces are brownish-black from hematin. Preparations of iron, bismuth, or lead, taken by the mouth, color the fæces black from the formation of the sulphides of these metals. Some green vegetables impart a brownish-green color, due to chlorophyll. The green color of infants' fæces is believed to be due to butyric and lactic fermentation, and the action of these acids upon the biliary coloring matters. In adults green passages may be due to a green microscopical plant, or **chlorococcus.**

The disagreeable odor of normal fæces is due in great part to indol and skatol. These are products secreted by the putrid bacteria, and come from the decomposition and transformation of albuminoid matters. Hydrogen sulphide, and sometimes a trace of hydrogen phosphide, contribute to the odor of fæcal matter.

The fæces contain, first: Alimentary substances which are assimilable, but which had been taken in excess, as starch, fatty matters in notable quantities, and a small proportion of non-assimilable proteids.

Second. Indigestible substances, such as vegetable fibre, cellu lose, chlorophyll, gums, pectic substances, resins, elastic tissue epidermic tissue, tendons, diverse coloring matters, nuclein, chi tin, insoluble salts (silicates, insoluble sulphates, ammonium magnesium phosphate, and calcium phosphate).

Third. Products coming from the digestive tube itself; intes tinal mucus, epithelia, cells, biliary acids (in part transformed a above described), cholesterin, lecithin, and bacteria.

Fourth. Substances which failed of absorption, as emulsified fatty matters, the free fatty acids, leucin, and biliary acids.

Fifth. Decomposition products due to microbic action, as the free fatty acids from acetic up to palmitic, this last quite abundant; also butyric, isobutyric and lactic, phenol, cresol, indol, skatol, stercorin, excretin, ammonium carbonate and sulphide, amins, amids, ptomains, leucin, tyrosin, phenylpropionic, phenylactic and parahydroxyphenyllactic acids. Some of these bodies, especially the ptomains, acids, phenols, and coloring matters, are absorbed, the phenols passing into the urine in combination with sulphuric acid, as sulphuric ethers.

Sixth. Pigments. The pigments found are stercobilin, hematin, biliary pigments, hydrobilirubin, and food-coloring matters.

Seventh. Gases. The origin of the gases of the intestine is partially from fermentation, partially from air swallowed with food and drink, and partially from diffusion from the blood or other tissues. The gases are composed of hydrogen, nitrogen, carbon dioxide, and marsh gas. The composition varies considerably with the character of the food, and the character of the fermentation, the length of time the food remains in the digestive canal, and the activity of the digestion. The discharge of carbon dioxid, frequently very great, which is rapidly produced in hysterical persons, probably comes from diffusion of the gases from the blood into the intestine and stomach. Marsh gas is derived from the fermentation of cellulose and other similar bodies. The nitrogen gas comes partially from swallowed air, but in small part from the blood and putrefactive fermentation. The following figures give the analysis of 1000 parts of fresh excrement:—

	ADULT MAN.	INFANT.
Water, ...	733.	851.3
Fixed solids, ...	267.	148.7
Total organic matter, ...	208.75	157.1
Mineral matter, ...	10.95	13.6
Alimentary residue, ...	83.	. . .

The analyses of excrement have their importance, principally, as a guide to the assimilation or malassimilation of food, and also because the excrement of various animals is employed as a fertilizer. The meconium, or the residue which accumulates in the intestinal canal during fœtal life, and which is passed soon after birth, contains bilirubin and biliverdin in abundance, also biliary acids, some fatty acids, the alkaline sulphates, chlorides, and the phosphates of calcium and magnesium. It does not contain urobilin, glycogen, peptone, lactic acid, leucin, or tyrosin. Two peculiar substances are found in fæces which do not occur elsewhere in the body. These are **excretin** and **stercorin,** or **serolin. Excretin** may be obtained from the fæces by making an alcoholic extract, and keeping it for a considerable time at a temperature below 0° C. (32° F.), when there is deposited an olive-colored granular body, having a fæcal odor and acid properties, from which Marcet has named it **excretoleic acid.** It resembles cholesterin in its properties. **Stercorin** is a body closely resembling cholesterin, and has frequently been confounded with it. It may be obtained from the dry fæces by exhausting with ether, filtering through animal charcoal, and allowing the ether to evaporate. Stercorin is left in the form of small, needle-shaped crystals, frequently in radiating groups.

MILK.

Milk is the secretion of the mammary glands, the presence of which is characteristic of the mammalia. The milk of different animals differs somewhat in composition, but always contains the same constituents. It contains all the necessary constituents of a perfect food, and is intended for the nourishment of the young until they are able to live upon other foods. Milk is an opaque, white fluid, containing fat globules in suspension, albumin, sugar, and salts in solution, and casein in partial solution. The reaction of human milk is generally feebly alkaline; that of the cow is usually neutral or faintly acid, while that of the carnivora is generally acid. Milk readily becomes acid or sour on exposure to the air, due to lactic fermentation. Microscopical examination reveals the fat in a state of perfect emulsion, the fat globules remaining suspended and separate from one another. The fluid seen between the globules is not perfectly clear, but contains small granules of casein, which may be filtered out by passing it through a clay filter. The milk which is secreted for the first few days after parturition, shows the presence of a few corpuscles
peculiar character. These corpuscles seem to be epithel

containing fat globules, which they have not yet liberated These cells are called **colostrum corpuscles**, and the milk o the first few days of lactation is called **colostrum**. It is believe by some that each fat corpuscle is surrounded by a shell, or membrane, of casein. Others deny the existence of this membrane

The specific gravity of milk is usually determined with th hydrometer. The specific gravity of cow's milk varies from 102 to 1035. An excess of fat lowers the specific gravity, and th removal of fat raises it. The addition of water will lower th specific gravity. These facts are made use of for the detection o the ordinary adulterations of milk.

The amount of milk secreted varies with the health of th animal, the amount of food taken, and various other conditions The amount secreted by a woman each day is about one liter A good cow secretes about 7 to 10 liters. The composition o milk varies in different classes of animals with the state of nutrition of the animal, the constitution, the age, the period of lactation, and the character of the food.

Composition of Milk.—The published analyses of milk ar very numerous, and the older analyses made by older method differ somewhat from the analyses made by more recent method The comparative composition of human milk and of cow's mil is given in the following table:—

ANALYSIS OF HUMAN MILK AND COW'S MILK (König).

	Woman's Milk.			*Cow's Milk.*		
	MEAN.	MINIMUM.	MAXIMUM.	MEAN.	MINIMUM.	MAXIMUM.
Water, . . .	87.09	83.69	90.00	87.41	80.32	91.50
Total solids, .	12.91	9.10	10.31	11.59	8.50	19.68
Fat, ...	3.90	1.71	7.60	3.66	1.15	7.09
Milk sugar, .	6.04	4.11	7.80	4.92	3.20	5.67
Casein, . . .	0.63	0.18	1.00	3.01	1.17	7.40
Albumen, . .	1.31	0.39	2.35	0.75	0.21	5.04
Albuminoids,	1.94	0.57	4.25	3.76	1.38	12.44
Ash, ...	0.49	0.14	?	0.70	0.50	0.78

Besides the constituents mentioned in the table, milk also contains very small quantities of certain extractives, among which are creatin, leucin, the odorous principle, etc. It also usually contains certain gases, principally carbon dioxide, oxygen, and nitrogen. Colostrum contains a larger proportion of solid matte than ordinary milk, a larger amount of albuminoid materials, and less sugar.

The proteids which occur in milk are probably three in number—caseinogen, lactalbumin, and lactoglobulin. Lacto-protea and peptone have also been described by some observers. When milk is allowed to stand at the ordinary temperature, a part of its lactose is converted by fermentation into lactic acid. When this has accumulated to a considerable extent, the caseinogen is precipitated. When milk is treated with rennin, or gastric juice containing this ferment, the caseinogen is rapidly converted into casein, and at the same time coagulation or precipitation occurs. When rennet is added to cow's milk, the result is a coherent clot or curd and a clear yellowish fluid called whey. The curd contains the fat entangled with the casein. The whey contains the albumin, sugar, and salts. In human milk the curd is formed of smaller flocculi, and the same appearance may be produced with cow's milk, if it is previously boiled or diluted with lime water. Caseinogen is often compared to alkali albumin; the latter, however, does not coagulate with rennet, and is readily soluble in acids, while caseinogen is not. Caseinogen resembles the globulins somewhat in its behavior with neutral salts. The globulins, however, coagulate when heated, while caseinogen does not.

Casein.—This name is sometimes restricted as above to the proteids formed by the action of rennet and acids, from the caseinogen of milk. Casein is the chief constituent of cheese.

Lactalbumin.—After the precipitation of the casein by acetic acid, this proteid is left in the solution. The scum which forms on the top of milk on boiling is probably formed by the coagulation of a part of the lactalbumin.

The boiling of milk before it is used as food is advantageous, in that all germs of disease are destroyed, and that the rennet gives a floccular instead of the heavy curdy precipitate. The lactalbumin is modified by the boiling, and precipitates on adding acid to the cold boiled milk.

Lactoglobulin.—Various observers have discovered other proteids than the two mentioned above. Lactoglobulin, whey proteid, lactoprotein, proteoses, peptones, and nuclein, have been mentioned as occurring in milk, but our knowledge of them is so slight that we will pass them with the mere mention. The lactoglobulin has the property of liquefying cooked starch, and of partially digesting it. This property is destroyed by sterilization.

Fat.—The chemical composltion of milk fat is very nearly like that of adipose tissue, with small quantities of the triglycerides of butyric, caproic, caprylic, myristic, and arachinic acids. Milk also contains minute quantities of lecithin, cholesterin, and yellow lipochrome.

Cream is simply the upper layers of milk which has been left to stand, and in which the fat globules are more numerous than in whole milk. The amount of cream that will separate from the milk in 24 hours is sometimes made use of as a test for the richness. A fair market milk will give from 10 to 12 per cent. of cream, while good milk will frequently give from 15 to 20 per cent., or even more.

Butter is the fat of milk in which the fat globules are broken up by mechanical agitation in the churn. About one-sixth of the fat remains in the buttermilk. Buttermilk contains, therefore, about from 0.5 to 1 per cent. of fat. Butter also contains small quantities of casein and lactose. Butter from human milk is richer in fluid fats than that made from cow's milk. By exposure to the air, butter becomes rancid, due to the breaking up of some of the glycerides of the fatty acids.

Milk Sugar, as will be seen in the above table, occurs to the extent of about 4.5 per cent. in cow's milk, and about 6 per cent. in human milk. The characteristics of this sugar have been described in Part V.

The Salts of milk are the phosphates of potassium, sodium, calcium, and magnesium, with chlorides of potassium and sodium, and a trace of iron, which is in combination in the nuclein.

Sterilized and Pasteurized Milk.—Owing to the ease with which milk undergoes the lactic fermentation and becomes sour, various methods have been tried to preserve milk for use in large cities. Subjecting the milk to a low temperature has been in use for a long time, and is of great service. Milk kept at a temperature of about 10° C. (50° F.) will keep sweet for a number of days.

For use as a food for infants, this has been found to be impracticable. Even with the greatest precaution, the lactic ferment will slowly progress and will grow in such abundance, as soon as the food is taken, as to disturb the child's digestion. This may and often is prevented by heating the fresh milk to 100° C. (212° F.) for 15 to 20 minutes, and then closing it up in an air-tight bottle or jar until needed for use. This "**sterilized milk**" is to be found in the markets. It has not met the success in use that was at first expected. The heat coagulates the lact-albumin, the globulin, and modifies the casein. On acidifying sterilized milk all the proteids are precipitated at once in a firm curd that does not afterward digest, but appears in the fæces. Experience shows that children fed upon this milk do not thrive.

The temperature at which these changes in the proteids begin is about 75° C. (167° F.). If milk is heated to this temperature, and not above, many organisms are killed, and others so weakened that the keeping quality is greatly improved, without altering the taste or composition. This process is called **Pasteurization**, and is now used to preserve milk for use as a food for infants.

Modified Milk.—By this term is meant cow's milk that has been changed in composition so as to resemble the composition of human milk. As the caseinogen of cow's milk is about three or four times that of human milk, and the albumin is but half that of human milk, there is a very decided difference in the digestibility of the two. Rennin coagulates the caseinogen only. The curd formed in the stomach from cow's milk is more abundant and forms tough masses, difficult to digest, while that from human milk is slight in amount and flocculent.

The sugar of cow's milk is present in about 4.5 per cent., while that of human milk is nearly 2 per cent. higher. These differences in composition make it necessary to modify the composition of cow's milk for the successful nourishment of many infants. Various methods have been proposed for accomplishing this, and have led to the production of numerous preparations put upon the market as baby foods.

The most successful of the attempts to modify cow's milk to imitate human milk, is a mixture of milk, cream, water, lime water, and milk sugar, made to correspond to the average analysis of human milk, and the mixture Pasteurized.

The milk used for this process, as well as the cream, must be fresh, and the cream should be of nearly constant composition. The only way to secure this is to use cream separated by the centrifugal machine.

With such a cream, containing 20 per cent. of fat, the following proportions will give very nearly the composition of average human milk (Rotch):—

Milk, ...	2 parts, or,	Milk, ...	4 fluid ounces.
Cream, ...	3 parts,	Cream, ...	6 fluid ounces.
Water, ...	10 parts,	Water, ...	20 fluid ounces.
Lime water, ...	1 part,	Lime water, . . .	2 fluid ounces.
Milk sugar, ...	½ part,	Milk sugar, . . .	7 drachms.

It is generally thought best to add the lime water at the time of feeding, but the author has usually added it before Pasteurizing.

The analysis of the above mixture will be about as follows, wh a good milk is used :—

Water, ...	88.42	Fat, ...	4	Sugar, ...	6.
Solids, ...	11.58	Albuminoids, . . .	1.11	Ash, ...	0.

The albuminoids in this mixture are too small in amount f most children after the first three months, and the milk and crea should then be used in equal volumes, for practical experien has shown that children thrive better on the latter proportions.

Changes in Milk Produced by Disease.—The mi of a strong, healthy woman is more nourishing than that the weakly, sickly woman. The character of the secretion milk in the human subject, as well as in some of the low animals, is greatly varied by the emotions, and milk secret during periods of excessive mental excitement has frequent proven poisonous to the young. Certain drugs pass throug the mother into the milk, as, for example, iodine, arsenic, ant mony, lead, zinc, bismuth, and mercury. Opium and morphin although they may not be detected in the milk, have frequentl passed into the milk in sufficient quantities to narcotize the i fant. In the cow the character of the food and the state of th health has an important bearing on the composition of the mil In cases of the cattle-plague the milk has been found to contai blood. The milk, in cases of tuberculosis, a common disease i cows, is capable of communicating this disease to calves, as we as to human subjects. Milk from tuberculous cows should nev be used. The milk from foot-and-mouth disease is also injuriou Milk is often the carrier of the infection of contagious disease as measles, scarlet fever, diphtheria, small-pox, and typhoid feve

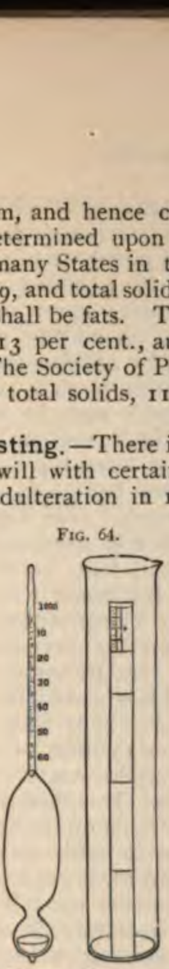
Milk is a good cultivating medium for the growth of vario bacteria, and several characteristic bacteria-producing colorin matters occur in milk, one giving it a blue, another a purpl red, and another a yellow color. Milk is sometimes rendere poisonous by certain bacterial growths. These poisons a either ptomains or tox-albumins produced by the growth of the bacteria.

The Adulterations of Milk.—The adulterations usuall practiced are, the extraction of cream and the addition of wate or both. Occasionally the addition of some foreign substanc as sodium carbonate, common salt, or sugar, is met with.

The detection of the adulterations of milk usually depen upon the determination of the specific gravity, the fat, tot solids, and the ash. The quantity of these ingredients is not pe fectly uniform, and hence certain limits of allowable variation have been determined upon from time to time. The standard adopted in many States in this country is, a specific gravity not less than 1029, and total solids not less than 12 per cent., of which 3 per cent. shall be fats. The legal limits for total solids vary from 12 to 13 per cent., and the solids not fat from 8.5 to 9.5 per cent. The Society of Public Analysts of Great Britain have adopted for total solids, 11.5, fat, 3, and solids not fat, 8.5 per cent.

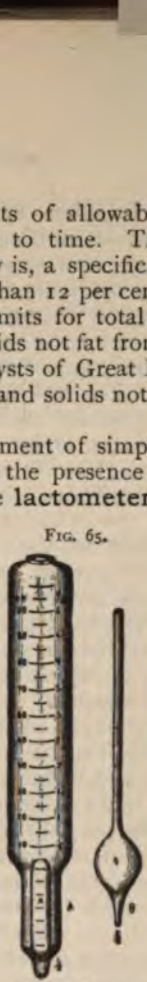
Milk Testing.—There is no instrument of simple construction which will with certainty detect the presence of a small amount of adulteration in milk. The **lactometer, or lactodensimeter,** which has been employed very largely in the sanitary inspection of milk, is a hydrometer with a scale covering the variations usually met with in milk. (See Fig. 64.) The **lactometer** of the New York Board of Health is a hydrometer on which the scale is so constructed that 100° indicate a specific gravity of 1029, the supposed lowest specific gravity of pure milk. The space between 1000, the specific gravity of water, and 1029 is divided into 100 arbitrary degrees. The scale is extended to 120°, which corresponds to a specific gravity of 1034. When taken alone it is of very little value. If,

FIG. 64.



HYDROMETER. (*Starr.*) CREAMOMETER. (*Starr.*)

FIG. 65.



FESER'S LACTOSCOPE. (*Queen.*)

however, it be taken with the estimation of either the to
solids or the fat, it is of considerable service. In very exc
tional cases the milk of a single cow may have a specific grav
below 1029, but such milk should be regarded as abnorm
Such depression of the specific gravity never occurs in t
mixed milk of several well-fed cows. A specific gravity bel
1029, therefore, unless accompanied by an excessive amount
fat, may be taken as evidence of contamination, probably w
water. The fat for such examinations may be estimated
the creamometer, or by some form of lactoscope, or the lact
butyrometer. The creamometer, or cream gauge, is simp
a graduated cylinder, the graduations being $\frac{1}{100}$ of the to
capacity of the cylinder to the O mark. (See Fig. 64.) T
milk is added in the cylinder to this zero mark, and
lowed to remain at rest for twenty-four hours, when t
number of the divisions covered by the cream is read off. Th
should not be less than 10 per cent. The **lactoscope** depen
upon the fact that the opacity of the milk is proportional to t
amount of fat which it contains. In **Feser's lactoscop**
(Fig. 65), a measured volume of milk is placed in a graduat
vessel, *A*, by means of the pipette, *B*. It is then diluted wi
water until the black lines of the inner cylinder of opaque whi
glass can be seen through the layer of the mixture between t
walls of the inner and outer cylinders. It is then only necessa
to read off the per cent. of fat on the scale of the outer cylinde
This method of determining the fat in milk, although answe
ing for the purpose of municipal control, is not to be depende
upon for scientific purposes, or as evidence upon which to ba
legal proceedings. The lactoscope is of value in estimating t
fat in human milk for clinical purposes. In a large experien
with this instrument the author has seldom seen the readings va
more than .3 per cent. from the accurate methods. Usually it
much nearer than this.

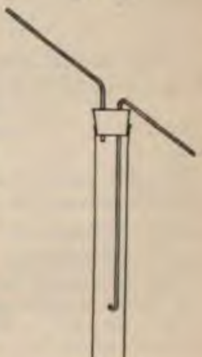
The Chemical Analysis of Milk.—An easy, rapid, an
satisfactory method for estimating the fat in milk, is that know
as the **Werner-Schmid Process.** Ten c. c. of the milk a
measured out into a long test tube, holding 50 c. c. and graduat
at every 10 c. c., and treated with 10 c. c. of strong HCl.
desired, the milk may be weighed into a small beaker glass an
then washed into the test tube with the acid, when the test tub
need not be graduated. After mixing the milk and acid togethe
the mixture is brought to a boil, or it is loosely corked and heate
in a water bath for 5 or 10 minutes, or until the liquid turns brow

but not black. The tube and contents are then cooled, 10 c. c. of well-washed ether added, corked, and the mixture well shaken. As soon as the ether separates from the remainder of the fluid, the cork is removed and the wash-bottle arrangement, shown in Fig. 66, inserted. The lower end of the exit tube is now adjusted by sliding it in the cork so that it is just above the line of separation of the two fluids. The ether solution of the fat is now blown off into a weighed beaker or flask. Two more portions of ether of 10 c. c. each are added, shaken up, and blown off into the first portion. The ether is now distilled off and the fat dried in a water oven and weighed. The amount of fat so obtained represents that contained in 10 c. c. of milk, or in the amount weighed out.

The results agree quite closely with the **Adams method** described below.

The **total solids and water** are determined by placing in a weighed platinum dish, a weighed quantity of the milk to be tested, say about 5 grms. This is then placed upon a water bath and evaporated to dryness. It is now transferred to the water or air oven, and dried at 100° C. until it ceases to lose weight. The loss in weight represents the water, the residue represents the total solids. Where great accuracy is unnecessary, the fat may be determined in the residue by treating it with warm ether and pouring this through a small filter, and repeating this process until the fat is completely dissolved out, which will require usually about 75 c. c. of ether. The ether is allowed to evaporate and the fat which remains behind is weighed; or, the residue left in the dish may be again weighed, when the difference between this weight and the weight of the dry solids will give the amount of fat. The results are about 0.3 too low. The ash may now be determined by igniting the residue left after treatment with ether, at a dull red heat, until all the organic matter is burned off, weighing the residue, and calculating it as ash. For many purposes the fat may be calculated from the specific gravity and total solids. This is especially useful in the clinical examination of human milk. It rests upon the assumption that

Fig. 66.



every per cent. of milk solids not fat, raises the speci gravity by a definite amount, while every per cent. of lowers it by a definite amount. An accurate determinati of the specific gravity and total solids will, therefore, furnish t necessary data for calculating the amount of fat. The formula which the calculations are made is that of Hehner and Ric mond. It is as follows: $F. = 0.859. T. - 0.2186\ G.$, in whi $F. =$ fat, $T. =$ total solids. and $G. =$ specific gravity, as e pressed in the third and fourth figures. Or, when the fat known, the formula may be transposed so as to calculate t total solids, as follows:—

$$T = \frac{F + 0.2186\ G.}{0.859.}$$

The specific gravity must be determined with care, and f rapidity only 5 c. c. of milk are evaporated to dryness to dete mine the total solids. This may be conducted in a watch gla using 2 or 3 c.c. if a platinum dish is not at hand.

To illustrate the use of these formulæ, let us assume in t examination of a given milk that the specific gravity, or G, w found to be 1030, that the total solids, on examination, gave per cent. Substituting these figures in the above formula, have:—

$$\text{Fat} = .859 \times 12 - .2186 \times 30 = 3.75.$$

Or if the fat has been determined, instead of the total soli and found to be 3.75 per cent., then—

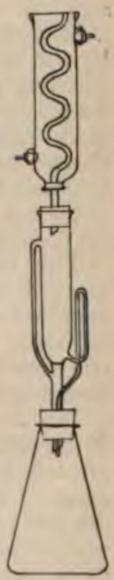
$$\text{Total solids} = \frac{3.75 + .2186 \times 30}{.859} = \mathbf{12.}$$

Another method has been proposed for calculating the solids not fat, fr data afforded by the lactometer, specific gravity and Feser's lactoscope, means of the formula $\frac{G - A}{.00375}$, where G equals the specific gravity of the m and A the remainder obtained on multiplying the per cent. of fat, as sho by the lactoscope, by .001 and deducting this from 1000. For exampl Suppose in a given sample of milk the specific gravity, or G, is found to 1030. The value of A in the above equation will be found by multiplying t per cent. of fat, 3.7, by .001, which will be equal to .0037, which, deduct from 1000, equals .997. Substituting 1030 for G, and this remainder, .9 for A in above equation, we have $\frac{1030 - .997}{.0037} =$ of total solid.

These short methods will be found useful in the examinati of human milk, where long, tedious processes are not likely be entered into. They are not to be mentioned as scientifical accurate, but are sufficiently so for clinical purposes and for t use of sanitary inspectors in sorting milks.

In the accurate estimation of the fat in milk the officially recognized method is that of Adams. Instead of drying the solids in the usual way, the milk is absorbed by bibulous paper previously thoroughly exhausted with ether and alcohol. This paper is usually cut in the shape of long strips, and these are rolled into a coil and put in a special apparatus known as an extractor, and shown in Fig. 67. The coil is put into the chamber of the middle piece of the apparatus, which is then connected with a condenser as shown. Sufficient ether to fill this chamber is put into the flask below, which is gently warmed. The ether distils up into the condenser and runs back upon the coil, filling the chamber until it flows over through the siphon tube into the flask below. This is repeated until exhaustion is complete. The ether is finally distilled off, and the fat in the flask is dried and weighed. The results obtained by this method are about .3 per cent. higher than those obtained by the method above described, of evaporating in a platinum dish and treating with ether. This has been adopted by official chemists, both in England and in this country, as the standard method of estimating fat. For the accurate estimation of fat in milk in well-equipped laboratories, it leaves little to be desired in the way of accuracy, but is a little difficult without these facilities.

FIG. 67.



Milk Standards.—For ordinary purposes, the estimation of the total solids, the fat and the ash, are considered sufficient to determine the question of the adulterations usually met with in the market. The standards that have been fixed by law in a number of the States all refer to specific gravity, fat, and total solids. Prosecutions are, therefore, usually based on these data. To calculate the per cent of pure milk in a mixture, the following formula may be adopted, based upon the legal standard of the State of New York, viz : 12 per cent. of milk solids, 3 per cent. of fat, and 9 per cent. of solids not fat.

9 : solids not fat : : 100 : x = milk used in making 100 parts of the mixture.

For other standards the first member of the equation will be the legal percentage of solids not fat. When the solids not fat are less than 9 per cent., it indicates some form of falsification. Suppose, for example, the solids not fat in any given analysis was 8·1. Substituting this in the above proportion we have —

$$9 : 8.1 :: 100 : x = 90$$

or this sample of milk had been made from 90 per cent. of milk and 10 per cent. of water. If the milk is skimmed the percentage of fat removed can be ascertained by the following formula :—

$$\tfrac{5}{9} \times S - F = x,$$

in which S = solids not fat, and F = fat found. Suppose, for example, the fat in a given case be 2 per cent. and the solids not fat 8 per cent. Substituting these in the above equation we have—

$$\tfrac{5}{9} \times 8 - 2 = x = 2.$$

That is, 2 per cent. of fat has been removed from this milk.

The Estimation of Sugar.—For ordinary purposes a sufficiently correct estimation of milk sugar can be made by exhausting the residue that remains after the extraction of the fat by the process above given with weak boiling alcohol. This dissolves the sugar and the soluble portion of the ash. The solution is filtered, evaporated to dryness in a platinum or a porcelain capsule, and weighed. The residue is then ignited and the ash weighed and deducted from the weight of sugar and ash, to obtain the amount of sugar.

Lactose may also be estimated with Fehling's solution, after the coagulation with acetic acid and removal of the casein.

The Determination of Casein.—Casein and albumin are generally determined by difference. When the direct determination is desired, they may be precipitated by tannin, the precipitate dried and washed with a mixture of 1 part of alcohol to 3 of ether until the washings show no trace of tannin. The whole is then dried and weighed.

The albuminoids can also be determined by the method of Ritthausen, who employs a solution of $CuSO_4$, containing 6.5 grms. to the liter and a solution of alkali of the strength of 14.2 grms. of KOH, or 10.2 grms. of NaOH to the liter. The copper salt precipitates the albuminoids together with the fat. Twenty c. c. of milk are taken, diluted with water to 400 c. c ; 10 c. c. of the copper solution added with constant stirring, until the coagulum settles and the supernatant liquid is clear. The alkali solution is now added until the liquid is neutral, and the contents of the beaker are filtered, using a dried and weighed filter paper. The precipitate is all transferred to the filter. It is washed first with water, then with diluted alcohol, and finally with ether, until all fat is removed. The remaining precipitate is again washed with alcohol and dried at 110° C. (230° F.) and weighed. The bluish mass is burned, and the loss, after deducting the weight of the filter paper, is reckoned as albuminoids.

Detection of Impure Water.—The addition of water to milk, if it be pure water, can be regarded as harmless to adults. It is rather a sophistication than a harmful adulteration. As this is usually well water, which may itself be impure, it becomes a matter of importance, because the water may carry with it germs of typhoid fever, cholera or other diseases, and will impart to the milk infectious properties. To detect impure water in milk the following process may be used: The milk is coagulated with acetic acid and filtered. To a suitable quantity of the whey add equal parts of a solution of naphthylamin sulphate and a freshly prepared solution of sulphanylic acid in sulphuric acid. The test may be made in an ordinary test tube or in a cylinder. If the milk contains nitrites, due to an impure water, a rose-red color will appear, varying in intensity with the amount of nitrites present, and deepening on standing. The test is very delicate. The following may also be employed: 100 c. c. of the milk is boiled with 1.5 c. c. of a 5 per cent. solution of $CaCl_2$, and filtered. A small portion of the filtrate is treated with H_2SO_4 containing 2 per cent diphenylamin. This mixture is then floated upon concentrated H_2SO_4, when, if nitrates or nitrites be present in the milk, a blue zone will appear at the line of contact of the two liquids. Or the above test may be applied as follows: One c. c. of a solution of diphenylamin in H_2SO_4 is placed in a small porcelain dish and a few drops of the milk allowed to flow down the side into the acid. If the milk contains nitrites or nitrates, a blue color will appear at the line of separation between the acid and the milk. This test is very delicate and will detect the presence of a very small quantity of impure water. Nitrites and nitrates are not found in milk, even if contained in the food of cows.

Condensed Milk.—Owing to the difficulty of keeping ordinary milk, several processes of preserving it by concentration have been employed. As early as 1837 Newton preserved milk by evaporating it in shallow pans at 50° C. (122° F.), during which time air was blown through the milk. From that time to the present, preserved or condensed milk has been an important article of commerce. When milk is simply evaporated without the addition of a preservative it is called **condensed milk**. This is also put into the market sometimes under the name of evaporated cream. This term is also applied to what properly should be termed **preserved milk**, or milk which has been condensed and cane sugar added. Preserved milk is much thicker in appearance than condensed. Milk is usually condensed to about one-third its original volume, although the makers usually claim that it is condensed to one-fourth its original volume. Analyses of a large number of samples made at various times in this country give the average as a little short of one-third. The addition of two parts of water to one of condensed milk should, therefore, produce a milk of the same degree of richness as the whole milk before condensation. Analyses made by Cornwall, of the condensed milks found in the American market, showed the following average:

Water, ...	26.95	per cent.	Milk sugar, ...	13.38	per cent.
Milk solids, ...	34.36	"	Cane sugar, . . .	38.82	"
Casein and albumin,	9.25	"	Ash, ...	1.92	"
Fat, ...	9.69	"			

Calculating from these results, he found that the condensation varied from 2.27 to 3.12 times, the average of all analyses being about 2.74 times, or the milk was condensed to not quite one-third the original volume. Condensed milk is largely used as a nourishment for young infants. For this purpose it is usually diluted with about 9 to 12 parts of water. Meigs has shown that if 1 part of the best commercial sweetened condensed milk be mixed with 9 parts of water, the mixture somewhat closely resembles in composition that of human milk, with the exception that it is deficient in fat, and that this mixture, with a small portion of cream added, gives a milk of nearly the chemical composition of human milk. In digestibility, condensed milk is inferior to cow's milk or human milk. It is open to the objection above mentioned to sterilized milk. It is open to the additional objection that a large part of the sugar present, when sweetened milk is used, is cane sugar instead of lactose, the natural sugar of milk. Cane sugar more readily undergoes acid fermentation in the stomach or intestine of the infant than lactose. Infants fed exclusively upon condensed milk show a tendency to develop rickets, or a failure of the nourishment of the bony structures. As a result, the development of the teeth, and the ability to walk are somewhat delayed.

THE URINE.

The urine is an excretory fluid thrown off by animals. It is partially filtered from the blood by the kidneys, and partly elaborated by these organs from waste materials found in the blood. It is composed of a watery solution of certain inorganic salts and nitrogenous principles which are of no further use to the body. As will be seen from the table on page 649, human urine is not a liquid of uniform composition, but subject to very considerable variations. These variations may be physiological, or they may be indicative of diseased conditions, and a knowledge of them is essential to correct a diagnosis of many diseases.

General Physical Properties.—Normal urine, when fresh, is a clear, amber-colored, transparent liquid, having a peculiar, aromatic, characteristic odor, a bitter saline taste, a distinctly acid reaction, and a specific gravity of from 1018 to 1022. The average specific gravity is generally given as 1018 to 1020. When it is kept in a clean vessel and away from contact with air, it will undergo but slight changes in several days.

Reaction.—Normal urine is faintly acid, and grows more acid for a few hours after being voided, due to the so-called "**acid fermentation.**" During this period of acid fermentation, there is frequently deposited a whitish or pinkish, or, at times, reddish sediment, due to the separation of the acid urate of sodium or to crystals of uric acid. This sediment dissappears again on warming the solution. On standing still longer exposed to the air, the acidity grows less and less, and at the same time an odor of ammonia begins to be developed, and finally the reaction changes from acid to neutral, and from neutral to alkaline, with a strong odor of ammonia and more or less odor of putridity. The rapidity with which these changes take place is dependent upon the condition of the secretion and temperature; taking place more rapidly in warm than in cold temperatures. An abundance of mucus, which can usually be seen after a few hours as a light, flocculent cloud, settling near the bottom of the vessel containing the fluid, greatly hastens these fermentative changes. This is especially the case if the bladder or the kidneys are in a diseased condition. There is produced with the mucus, especially in diseased conditions of the bladder, a peculiar soluble ferment, which hastens the above changes.

The reaction of urine is best tested by dropping a small piece of a red and a blue litmus paper into the solution. If both are found red after a few minutes, the reaction is acid. If both are blue, it is alkaline. If they remained unchanged, the reaction is said to be "amphoteric." If the alkalinity be due to ammonium carbonate, the red paper, on drying and warming over a flame, turns red again. If due to the fixed alkalies, it remains blue on drying and warming.

The fermentation of urine is due to certain microörganisms, of which the **torula ureæ** is the best known. Normal urine is free from these organisms when passed, but in certain abnormal conditions it may undergo an alkaline fermentation while still in the bladder, and that apparently without the intervention of these organisms. It has been found that the fermentation may be complete in the presence of an amount of carbolic acid which is fatal to the development of microörganisms. It has been assumed that an enzyme is secreted with the thick mucous secretion of urinary catarrh, which possesses active hydrolytic powers on a solution of urea. As the urine becomes alkaline from the production of ammonium carbonate from urea, it becomes turbid and acquires a paler color. The turbidity is due to the precipitation of the phosphates of calcium and magnesium, the oxalate of calcium, and microörganisms. The phosphate of calcium and ammonium-magnesium phosphate, which separate when the urine becomes alkaline, are generally called the **earthy phosphates.** The latter of the two is called the triple-phosphate, and is found in nearly all alkaline urines.

Composition.—The urine is chiefly a solution of urea and certain organic and inorganic salts, holding in suspension epithelial cells and mucus. The composition will be found in the table at the end of this chapter, with the chief variations met with in diseased conditions and their significance. The urine, like the milk and other animal fluids, is not of constant composition. It is influenced by the amount of water and other fluids taken, by the temperature of the skin, by the emotions, by the blood pressure, local or general, the amount of work done, the time of day, the age, the sex, influence of medicine, etc.

The **quantity** of urine passed in 24 hours varies considerably. The average daily quantity passed by a healthy adult is from 1400 to 1600 c.c., or about 50 fluid ounces. The quantity of total solids contained in this is about 60 grms., or 1000 grs., and about one-half of these solids is composed of urea.

The variations in the quantity will be found in the table at the close of this chapter.

The Color and Transparency.—In health, the color is usually a light amber. In general, the greater the quantity the lighter the color; and, *vice versa*, the smaller the quantity the higher the color. As the color deepens by concentration it becomes more reddish. The color, as well as the quantity, is subject to great variations, even in health. It may vary from almost as clear as water to a dark yellowish-red, according to the degree of concentration. After drinking large quantities of fluids the quantity is very much increased and the color is light. After severe sweating, or in abstinence from drinking, it becomes concentrated and darker in color. The normal color of the urine is due to several more or less closely allied pigments, the chief of which are **urobilin** and **indican**, or **uroxanthin.** These coloring matters are probably decomposed products of the biliary coloring matters. The abnormal coloring matters are chiefly those of the blood or bile, melanin, hemoglobin, and coloring matters due to medicinal substances and certain vegetables. An excess of the normal pigments of the urine may be expected in febrile conditions, and in diseases in which the blood cells are undergoing rapid destruction. Urobilin, when it exists in excessive quantities, colors the urine a dark brownish-red, even without concentration, and the foam of such a urine is a yellow or yellowish-brown color. There is a marked increase of urobilin in conditions where the hepatic cells fail to perform their proper function, that is, in the condition known as biliousness. In such cases the skin and other tissues may also show the presence of the same yellow color.

The Tests for Urobilin.—First. The spectroscopic examination shows absorption bands in the green, between the lines *b* and *F*. In order to see these lines, it is often best to dilute the urine by pouring water carefully upon the top of the heavier urine in the test-tube. After allowing the liquids to remain at rest for a short time, examine the water above the urine for the absorption bands.

Second. Chemically, we may test for urobilin by the addition of ammonia to the urine, when, if much urobilin be present, it gradually assumes a greenish hue. It is then filtered and a watery solution of $ZnCl_2$ added, when there appears a rose-red color with greenish fluorescence, due to urobilin.

Indican or **Indoxyl-Potassium Sulphate,** $C_8H_6NO\,SO_3K$, occurs in normal urine, but it occurs in increased quantities when there is an accumulation of the intestinal contents, as in occlusion, in peritonitis, or obstinate constipation. It is probably not due simply to the accumulation of the intestinal contents, but to the putrid fermentation of the contents when too long retained. The presence, then, of an excess of indican is an index of the amount of intestinal putrefaction. Indican is always found in all forms of severe cachexia, in carcinoma of liver, phthisis, typhoid fever, dysentery and in Asiatic cholera. It is detected in increased amounts by the addition of an equal volume of strong nitro-hydrochloric acid, and dropping into this 2 or 3 drops of a concentrated solution of chlorinated soda. Immediately, or after a few seconds, there is formed just beneath the surface a bluish-black cloud of indigo. By stirring the chlorinated soda solution into the urine, we obtain, according to the quantity of indican present, a more or less dark coloration of the whole fluid. If we now shake the fluid with chloroform, the indigo is dissolved out by the chloroform, and settles as a blue layer at the bottom. Care must be taken not to add too much of the chlorinated soda. **Uroerythryn** and **urochrome** have been described as occurring in urine, but little is known of them.

The coloring matters of the bile and the blood will be considered again.

Certain medicines and vegetables may color the urine. Rhubarb and senna color the urine a brownish color, but if alkaline, or if made alkaline, it becomes a purple-red. The coloring agent in this case is the chrysophanic acid found in these medicines. After taking logwood, the urine becomes reddish, or violet when made alkaline. Santonin colors it yellow or greenish-yellow, which, on the addition of an alkali, changes to red. Picric acid also gives a yellow color, which does not change to red on the addition of an alkali. Phenolnaphthalin, creasote, preparations of tar, or arsin (AsH_3), impart either a greenish or a greenish-black color to the urine. Brown or brownish-black urine is observed in patients with melanotic tumors. The coloring matter in this case is melanin.

Transparency.—Normal urine is transparent, containing only a slight flocculent cloud of mucus, visible after standing a few minutes. If the urine is turbid when passed, it is pathological. It is usually turbid in all diseases of the urinary passages, from the excessive amount of mucous and epithelial elements, and because the urine in this condition readily undergoes alkaline fermentation in the bladder, when the earthy phosphates are precipitated as a white sediment. In fevers, the quantity of urine is occasionally so small that the urates separate even in the bladder, and especially is this the case in certain diseases of children where the oxidation is deficient, as in capillary bronchitis and pneumonia. Admixtures of blood, pus, and chyle make the urine turbid. The most striking turbidity is produced by the admixture of chyle, which gives a milky-white appearance. Here the milky appearance is due to an admixture with the urine of emulsified fat and imperfectly dissolved proteids. Many urines which are clear when passed, become turbid on standing, from the separation of the acid urates of sodium or ammonium. The turbidity of alkaline urine has already been mentioned.

Specific Gravity.—This varies from 1015 to 1028, according to the degree of dilution or concentration. Pathological urines may vary from almost that of water to 1050. As a rule, the urine of Bright's disease is of low specific gravity, and in diabetes mellitus of high specific gravity. The specific gravity of urine is generally determined by the urinometer, which is a small hydrometer graduated to include the variations in specific gravity usually found in urine. (See p. 13.) It is usually graduated so that only the last two figures of the specific gravity appear upon the stem, and so as to read correctly at 60° F. If the temperature is above 60° F., it will be sufficiently accurate for clinical purposes to add one degree in specific gravity for every ten degrees in temperature, *i. e.*, if it read 1018 at 80° F., it would read 1020 at 60° F. The ordinary urinometers of the market are apt to be unreliable. It is best, therefore, to test the instrument by careful determinations of the specific gravity of solutions of common salt, with the specific gravity flask, and compare the readings of the urinometer with these determinations.

The urinometer is used as follows: The urine is placed in the upright jar, or cylinder, wide enough to allow the instrument to float freely, and deep enough to float it When it has come to rest, the surface of the fluid in the jar is brought to the level of the eye, and the reading taken at the lower edge of the meniscus formed by the upper surface of the urine. The mark on the instrument which is cut by this line, and which can be distinctly seen, is taken as the correct reading. If the urine be turbid, this method cannot be employed, as the reading will be more or less uncertain.

Total Solids.—As stated before, the normal amount of solids passed by an adult in twenty-four hours is about 60 grms., or 1000 grs. An approximate estimation of the total solids may be made by multiplying the last two figures of the specific gravity, carefully taken, by the factor 2.33, which will give the number of grms. of solid matter in 1000 c. c of urine, from which it will be easy to calculate the amount in 24 hours. If, for example, the quantity in 24 hours be 1500 c. c., and the specific gravity 1020, the total solids would be 20 × 2.33 = 46.6 grms. of solids in 1000 c. c. in 1500 c. c. there will be 1.5 as much, or 69.9 grms. If it be desired to use English measures, we may determine the total solids by multiplying the last two figures of the specific gravity by the number of fluid ounces passed. Thus, if the number of fluid ounces be 50, and the specific gravity 1020, then the total solids will be 50 × 20 = 1000 grs. These methods of caculating the total solids give only approximate results, but in most cases will be found sufficiently accurate for clinical purposes.

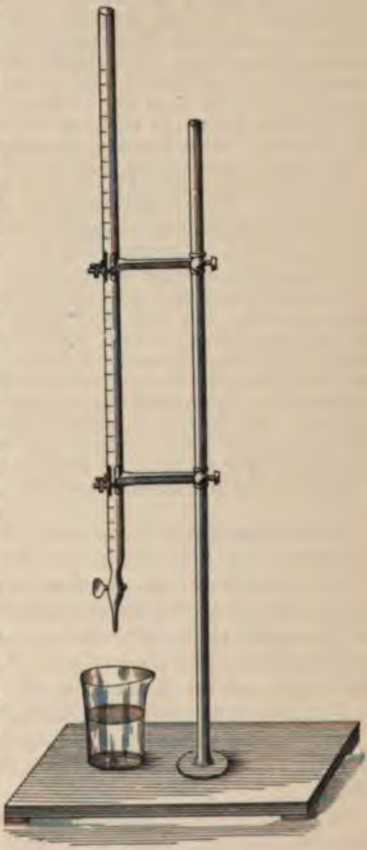
A more exact method for determining the total solids, is to evaporate 10 c.c. in a porcelain dish or watch-glass, and dry in a water oven to constant weight. The difference between the weight of the dish and of the dish with the solids, will give the weight of the solids in 10 c.c. of urine. Even by this method there is some loss during the evaporation.

Odor.—The odor of normal urine has been described as aromatic. A putrid odor is due to the odor of products of decomposition. Occasionally the urine is putrid when passed, the putridity being due to the putrid fermentation of pus, albumin, or some other foreign matter mixed with the urine in the bladder. Sulphuretted hydrogen sometimes occurs in the urine, and a fæcal odor is occasionally met with, indicating a fistulous opening between the bladder and the intestine, or from abscesses between the bladder and rectum. A number of substances, when taken internally, cause the urine to assume a characteristic odor. Many aromatic substances impart their odor, as oil of turpentine (giving the odor of violets), cubebs, copaiba, asparagus, garlic, valerian, etc.

Inorganic Constituents of the Urine.—The urine contains certain inorganic salts, which are especially the chlorides of potassium and sodium, the phosphates of potassium, sodium, magnesium, and calcium, and the sulphates, or sulphuric ethers of indol and skatol. These salts are generally tested for by the detection of the corresponding acids.

Chlorides.—For the detection of the chlorides add a few drops of nitric acid, and then a solution of silver nitrate (1 to 10). The chloride of silver separates as a white, curdy precipitate, which should occupy not more than one-fourth the volume of the urine taken. If the settled precipitate occupies much more or less than one-fourth the volume of the quantity of urine taken, the quantity is increased or diminished. It is always best in making this test, to compare the specimen under examination with normal urine. In most cases this approximate estimation of the chlorides will be all that the clinician will demand. Occasionally, however, it becomes necessary to make a more accurate determination. For this purpose it is necessary to have a decinormal solution of silver nitrate, *i. e.*, a solution containing 16.96 grms. of pure silver nitrate, dissolved in a liter of distilled water.

FIG. 68.



GRADUATED BURETTE.

Quantitative Estimation of Chlorides.—Dilute 10 c.c. of the urine with about 50 c.c. of water and add a few drops of a rather strong solution of potassium chromate. Now drop the silver solution from a graduated burette (see Fig. 68) drop by drop, until a permanent reddish color indicates that the chlorine has all been precipitated, and that the silver has begun to form silver chromate. 10 c.c. of urine usually requires 15 to 20 c.c. $AgNO_3$ solution. 1 c.c. of silver solution represents 0.00354 grm. of chlorine, or .00584 grm. of NaCl. In highly colored urines this method is sometimes inapplicable, owing to the change of color being masked by the color of the urine. In such cases it is best to use the following method.

Second Method.—When to a solution of silver nitrate, acidulated with nitric acid, sulphocyanate of ammonium or potassium is added, a white precipitate forms, which is insoluble in nitric acid. If the fluid contains a ferric salt, a blood-red color forms at the moment when the last of the silver is precipitated. **Volhard's** method of estimating the chlorides makes use of this principle. The following solutions are needed in the process: 1. Pure nitric acid. 2. A strong solution of ferric alum (sulphate of iron and ammonia) free from chlorine. 3. A decinormal nitrate of silver solution made by dissolving 16.96 grms.

in a liter of distilled water. 4. A decinormal solution of potassium sulphocyanate or of ammonium sulphocyanate. This should be of exactly the same strength as the silver solution. It is made by dissolving 6.5 or 7 grms. of the sulphocyanate in about 400 c.c. of water. To standardize the sulphocyanate solution a portion of it is put into a burette and 10 c.c. of the decinormal silver nitrate solution brought into a beaker with a few drops of the solution of iron alum. The mixture is well stirred and the sulphocyanate solution added drop by drop until a slight but permanent red color appears. In accordance with the result obtained, the sulphocyanate solution is diluted to such a point that 10 c.c. of it will just neutralize 10 c.c. of the $AgNO_3$ solution. If, for example, 8 c.c. of the sulphocyanate produce a red color, we then know the amount of sulphocyanate in 8 c.c. is that which should be in 10 c.c. Therefore, we dilute the 8 c.c. with a sufficient amount of water to make it 10 c.c., or if we have 500 c.c. we shall add to every 8 c.c., 2 c.c. of water, or we make the calculation by the following proportion:—

$8 : 10 : : 450 : x = 562.5$, or 450 c.c. of the solution first made up will require to be diluted to 562.5 c.c., or there must be added 125.5 c.c. of water. Having thus corrected this solution to make it agree in strength with that of the silver solution, we again compare them to see if it is correct.

The process is conducted as follows: 10 c.c. of the urine are measured out with a pipette, and placed in a graduated flask of 100 c.c. capacity. Fifty c.c. of water are added, and then, successively, 4 c.c. of nitric acid and 25 c.c. of silver solution. The flask is closed with a glass stopper, and agitated until the precipitate ceases to form, and the fluid tends to clear. Distilled water is added to the 100 c.c. mark. A portion of the fluid is then passed through a dry filter, and when 50 c.c. have run through, a few drops of the iron alum solution is put in, and then the sulphocyanate solution run in until a red color appears. The amount of sulphocyanate solution added, deducted from the amount of silver solution added, gives the amount of silver used up by the chlorine in ½ of the 10 c.c. of urine, or 5 c.c.

The calculation is the same as in the first method.

Phosphates.—Phosphoric acid exists in the urine combined with the alkalies (about ⅔), and with lime and magnesium. These phosphates are, therefore, generally distinguished by the terms **alkaline** and **earthy phosphates.**

The **acidity** of the urine is generally believed to be due to the acid sodium phosphate (NaH_2PO_4). Sodium phosphate (Na_2HPO_4) is neutral in reaction, and Na_3PO_4 is alkaline.

In acid urines we have NaH_2PO_4, Na_2HPO_4, $CaHPO_4$, $CaH_4(PO_4)_2$, and $MgHPO_4$; while in alkaline urines we find in solution Na_3PO_4, and as precipitates $Ca_3(PO_4)_2$, $Mg_3(PO_4)_2$, and $MgNH_4PO_4$.

By adding an alkali to normal urine the phosphates of calcium and magnesium, termed earthy phosphates, are precipitated. The phosphates of sodium and potassium remain in solution. The earthy phosphates may be approximately estimated by adding a few drops of ammonium hydroxide solution to the urine, and observing the amount of turbidity produced after boiling.

By comparing this with the amount obtained by the same treatment of normal urine, it will indicate whether the quantity is excessive or deficient. The alkaline phosphates may be detected in the filtrate from the earthy phosphates, by the addition of a few drops of $MgSO_4$ solution and some NH_4Cl. This precipitate should be much more voluminous than that produced by the earthy phosphates, and whether in excess, normal or deficient, may best be determined by comparison with normal urine. The quantitative estimation of the phosphates is rarely required.

Sulphates.—Sulphuric acid occurs in the urine partly in combination with the metals, and partly in combination with certain aromatic bodies of putrefactive origin, called collectively the ethereal sulphates. The most important of these are phenol- and cresol-potassium sulphates, indoxyl- and skatoxyl-potassium sulphates, pyrocatechin- and hydrochinon-potassium sulphates. The sulphates are detected by the addition of $BaCl_2$ in the presence of free HCl. They appear as a fine white precipitate of $BaSO_4$, rendering the solution opaque, and milk-like in appearance. An approximate estimate may be made by comparing the turbidity with that of normal urine treated in the same way. An excess of sulphuric acid generally indicates an excess of putrefactive decomposition in the intestines, unless it should be due to the taking of an excessive amount of sulphates with food or drink. It is the ethereal sulphates that have the chief clinical interest. They are derived from the putrefactions of proteids in the intestines, and the quantity of them present in the urine is usually taken as a measure of the intestinal putrefaction. They are decomposed, on boiling with dilute mineral acids, into free sulphuric acid and phenol. The sulphuric acid which they contain is not precipitated in the cold by a slightly acidulated solution of barium chloride. An approximate estimation of these ethereal sulphates may be made by precipitating the urine with an excess of barium chloride and a few drops of hydrochloric acid, filtering off the precipitated $BaSO_4$, and then adding to the filtrate one-tenth its volume of pure HCl, boiling and heating on a water bath for one hour. The $BaSO_4$ obtained after this treatment of the filtrate, represents the sulphuric acid existing as ethereal sulphates.

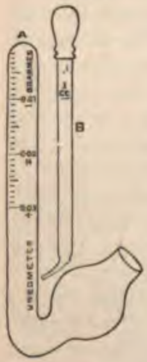
Organic Constituents.—Urea, $CO(NH_2)_2$.—Urea is the most important constituent of the urine, as it is the chief condition in which nitrogen leaves the body. It is by far the most abundant solid ingredient of the urine. Its chemical properties have already been described.

The **qualitative** detection of urea may be made by evaporating a few drops of urine on a glass slide, moistening with nitric acid and allowing it to crystallize, and examining the crystals of urea nitrate, $CO(NH_2)_2HNO_3$ under a microscope of low power.

The **quantitative** estimation of urea in urine is a matter of considerable importance, as it is generally looked upon as an index of the retrograde or destructive changes going on in the body, or of the eliminating power of the kidneys. The quantity of urea in 24 hours has been put down at from 30 to 33 grms., or from 430 to 550 grs. The quantity will be increased by the increased consumption of a nitrogenous diet, or by increased exercise, and it will be diminished by a non-nitrogenous diet and by lessened exercise. In estimating what should be regarded as a normal amount of urea, the condition of the patient, as to exercise, appetite, and dietary, should be taken into account. Roughly, in the absence of sugar, albumin, and other abnormal ingredients, the urea may be regarded as one-half the total solids. The more accurate quantitative estimation requires so little time, apparatus and skill, that it is now generally employed. The determination is based upon the fact that urea is decomposed by alkaline hypochlorites or hypobromites into carbon dioxide, water and nitrogen.

$$CO(NH_2)_2 + 3NaBrO = 3NaBr + CO_2 + 2H_2O + N_2.$$

FIG. 69.



One c. c. of nitrogen at the ordinary temperature and pressure corresponds to about .0027 grms. of urea.

The liberated N escapes and may be collected and measured, while the other products of the reaction remain in solution.

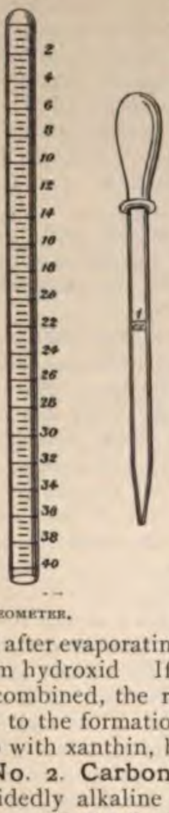
The hypobromite solution is prepared as follows: 100 grms. of NaOH are dissolved in 250 c. c. of water, and to this solution, when cold, 25 c. c. of bromine are added, and the solution kept cold. This solution contains sodium hypobromite, hydroxide, and bromate. The solution should be freshly prepared, as it readily undergoes decomposition. Owing to the instability of this solution and the excessively disagreeable handling of bromine, the author employs a solution of sodium hypochlorite, or chlorinated soda, with the addition of KBr. This solution acts as well, by the method to be described, as the above. Various forms of apparatus have been devised for the quantitative estimation of urea. The simplest of these is the one devised by Dr. C. A. Doremus, which is represented by Fig. 69. The tube, A, is filled with the above-mentioned solution of hypobromite, and 1 c. c. of urine is introduced with the pipette, B, as nearly as possible at the centre of the lower portion of the upright limb. The urea is decomposed and the N rises to the upper closed end. After the decomposition is complete, the urea is determined by reading the graduations at the surface of the column of liquid. This ureometer, according to the graduation, gives either the mgrms. of urea in 1 c. c. of urine, the per cent., or grs. per fluid ounce.

The author uses a graduated tube closed at one end. The graduations indicate at once the number of grs. of urea in a fluid ounce of urine, when 1 c. c. is taken for the estimation. (See Fig. 70.)

The process is conducted as follows: A 25-per cent. solution of KBr is added to the fifth division. The chlorinated soda solution is then added to the fifteenth and twentieth division. The tube is now inclined and pure water poured carefully down the side of the tube and floated upon the top of the fluids already in. 1 c. c. of urine is then added, in the same inclined position, so that it will not mix with the reagents below, but remain in the water at the surface of the fluid. The open end of the tube is now quickly closed with the thumb, and the top firmly grasped in the right hand. The tube is now inverted, and the contents well mixed. A rapid decomposition takes place, which is usually ended in from three to five minutes. During this time the liquid is kept agitated without violent shaking. As soon as the effervescence has ceased, the reading is taken at the surface of the fluid, with the tube still held in the inverted position. It is now opened under water, when the column of fluid in the tube will fall, and the reading is taken again. It is best to have a wide, deep jar for the water, so that the tube may be depressed to bring the surface of the liquid in the tube to the surface of the water in the jar; but an ordinary bowl may be used, as the error caused by the difference of three or four inches of water is very slight. The difference in the two readings gives the number of grains of urea in a fluid ounce of urine. This quantity, multiplied by the number of fluid ounces passed in twenty-four hours, gives the amount of urea excreted in twenty-four hours, which should be not far from 500 grains. A less quantity than 350 grains in an adult, who is eating the usual amount, should be regarded as pathological, and suspicious of nephritis, or deficient kidney excretion.

Uric Acid, $C_5H_4N_4O_3$, is a constituent of normal urine, sometimes occurring in the free state, but oftener in combination with potassium, sodium, ammonium, and occasionally with calcium and magnesium, usually called collectively **urates.** For the description of this acid see Part IV.

Fig. 70.



UREOMETER.

Uric acid is soluble in 14,000 parts of cold water, and is, therefore, frequently met with as a sediment, and is then detected by microscopical examination. In quantity it varies from .4 to .8 grm. (from 6 to 12 grs.) in 24 hours.

Detection.—It is best recognized when in the free state by the microscope. The crystals, as seen with this instrument, are colored yellow or reddish, and appear in a variety of shapes, the most common being the "lozenge" or "whetstone" shape. They are sometimes large enough to be seen with the naked eye, when they appear as minute, garnet-colored grains adhering to the sides or upon the bottom of the vessel.

Chemical Tests.—No. 1.—Murexid Test.—Evaporate a portion of the urine to dryness in a porcelain dish upon a water bath. Moisten the residue with nitric acid, and after evaporating off the acid, moisten the residue with ammonium hydroxid If uric acid be present, either in the free state or combined, the residue assumes a beautiful purple red color, due to the formation of murexid. The reaction is said to occur also with xanthin, hypoxanthin, tyrosin, and some other bodies.

No. 2. Carbonate of Silver Test..—Render the urine decidedly alkaline with Na_2CO_3 or K_2CO_3, and moisten a filter paper with the liquid. Now touch the moistened paper with a solution of $AgNO_3$. A distinct gray stain indicates the presence of uric acid.

The quantitative estimation of uric acid is tedious and difficult. The usual method is to acidify the urine with HCl and set aside for 24 hours. At the end of that time the uric acid, which has been set free by the HCl, separates out, owing to its insolubility, and is found adhering to the sides and bott of the vessel. It is collected on a weighed filter, washed thoroughly, a dried at 100° C. (212° F.), and weighed. The weight of the filter with contents, minus the weight of the filter alone, gives the weight of the uric a in the volume of urine taken.

The acidity of the urine increases with the amount of uric acid excreted. The **total acidity of normal urine** is equivalent to the acidity of 2 to 4 grms. of oxalic acid in 24 hours. The greater part of this acidity is due to the acid sodium phosphate produced by the reaction of uric acid upon Na_3PO_4, and the rest is due to the organic acids, most likely lactic.

The acidity may be estimated by a decinormal solution of sodium hydroxide 25 c.c. of the urine are diluted with 75 c.c. of water in a beaker. Three drops of an alcoholic solution of phenolphthalin are added, and a decinormal alkali run in from a burette, until a slight pink color is produced. The urine must be fresh for this estimation. The acidity may be calculated as phosphoric acid, as acid sodium phosphate, or, as is frequently done, as oxalic acid. Each c.c. of the decinormal alkali is equivalent to 0.0049 grm. of phosphoric acid, or 0.012 grm. (.01198 more exactly) of acid sodium phosphate, NaH_2PO_4, or 0.0063 of oxalic acid. Each molecule of acid sodium phosphate, or each 120 parts, is equivalent to one-half molecule, or 84 parts of uric acid, as will be seen by the following reaction:—

$$Na_3PO_4 + 2C_5H_2N_4O_3H_2 = 2NaHC_5H_2N_4O_3 + NaH_2PO_4.$$

Hence, each c.c. of decinormal alkali is the equivalent of 0.0084 of uric acid.

ABNORMAL CONSTITUENTS OF URINE.

These are albumin, globulin, albumose, peptone, glucose, acetone, diacetic acid, bile-coloring matters and acids, blood, blood-coloring matters, pus, chyle, and abnormal sediments, such as casts, excessive amount of epithelium, mucus, etc.

Albumin.—Albumin is found in the urine at times without apparent disturbance of health. Usually, however, it is regarded as pathological, and is so often associated with the various inflammatory diseases of the kidney, that its presence is often taken as evidence of some one of these diseases. It occurs principally in the form of serum albumin. It is coagulated in the urine by a temperature of from 73 to 75° C. (163.4 to 167° F.). In all cases, the urine should be clear before applying the tests for albumin If not clear it should be either settled and decanted or filtered. The tests for albumin usually depend upon its coagulation, and the formation of a turbidity in the solution. A few tests depend upon a change in color. The tests that are most satisfactory, when applied to the urine,

1. Heat about 5 c.c of the urine to b It

is then examined for even the slightest amount of turbidity. This turbidity, if present, will be due to **albumin** or **earthy phosphates.** Now add, slowly, a few drops of ascetic or nitric acid. If the turbidity be due to the phosphates, it disappears, while if it be due to albumin, it remains permanent. Care must be taken in the addition of the acid, after boiling, to note the effect after each drop is added, and to go on adding until there can be no doubt that the urine is distinctly acid. This test will show traces of albumin under the most favorable conditions.

2. **The Contact Method.**—Place 2 c.c. of pure HNO_3 in the test tube, and, inclining the tube to one side, pour the urine carefully down the side of the tube so that it may float upon the acid. This is best done with a pipette, or by pouring the urine from one test-tube into another, holding both in a nearly horizontal position. If this be done carefully, there will be very little admixture of the two liquids. If albumin be present, a white, opaque zone of coagulated albumin appears at the line of contact of the two fluids. A brown zone will frequently be seen at this point, which grows in intensity on standing, and is due to the action of the acid on the coloring matters, but it does not give any turbidity unless albumin is present. If bile be present, the color may be green; if blood, brown-red. This test is decidedly more delicate than No. 1.

Precautions.—Occasionally after the administration of turpentine, or balsams and resins, these are precipitated by HNO_3 as a yellow-white cloud, which, however, is soluble in alcohol I have never seen the uric acid, sometimes set free by HNO_3. to even resemble the precipitated albumin, so as to give any possibility of a mistake. Roberts modifies this test by using, instead of pure nitric acid, a mixture of one volume of HNO_3 and five volumes of a saturated solution of $MgSO_4$. This reagent is as sensitive as HNO_3, and pleasanter to handle. It is used in the same way.

3. Acidulate the urine with acetic acid, filter if much mucin is precipitated, and then add a few c.c. of a solution of potassium ferrocyanide. Or, better, float the acidulated urine over the K_4FeCy_6 solution. If albumin be present, it appears as a white precipitate. This reagent does not precipitate peptone, mucin or alkaloids. It is a very delicate and reliable test.

4. A cold, saturated solution of picric acid may be used by the **contact method.** At the line of contact, the albumin appears as a white zone. No previous acidulation of the urine

is usually required. Some prefer, however, to add acetic acid to insure decided acidity. Heat afterward to dissolve alkaloids, mucin, peptones and urates, which are precipitated with the albumin. It is better to heat the urine before adding the test solution.

5. **Sodium Tungstate Solution.—Reagent:** Made by mixing equal parts of cold saturated solution of sodium tungstate and citric acid. As its specific gravity is heavier than that of urine, it is best applied by the contact method. This is an extremely delicate test, and precipitates at the same time peptones, mucin, some alkaloids and urates, which are dissolved by heating.

6. **Tanret's Test.—Potassio-Mercuric Iodide Test.**—Reagent prepared as follows: Mercuric chloride 1.35 grms., potassium iodide 3 32 grms., acetic acid 20 c. c., distilled water 80 c. c.; the $HgCl_2$ and KI are separately dissolved in water and then united, and the acetic acid afterward added. The rusulting liquid is heavier than urine (specific gravity 1040), and is best used by the contact method. It is exceedingly delicate, detecting 1 part of albumin in 20,000 parts of urine. Heat to dissolve the alkaloids mucin and peptone, as in tests 4 and 5.

7. **Acidulated Brine Test.—Reagent:** To a pint of a saturated solution of common salt add one ounce of HCl and filter if necessary. This is a delicate test for albumin when properly used. It has a high specific gravity and is best used as follows: The solution is heated to boiling and the urine added by the contact method. If albumin be present. it appears as a zone at the contact surface. It does not precipitate peptone, albumose, or the alkaloids.

8. **Trichloracetic Acid.**—This is a white, crystalline acid, sometimes employed as a test for albumin. It may be used in the form of a saturated solution, by the contact method, or the crystals may be added directly to the urine, when they will form a strong solution at the bottom of the tube. It presents no decided advantages over the tests above mentioned.

9. A solution of **salicyl-sulphonic acid** in water is a very delicate test for all forms of albumin, and is to be recommended because it does not precipitate peptone, mucin, or the alkaloids. It is a white, crystalline compound, formed by saturating strong H_2SO_4 with salicylic acid, and setting aside to crystallize

Metaphosphoric, or **glacial phosphoric acid,** has also been recommended by some as a reliable test for albumin in urine.

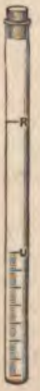
Albumin test papers, suggested by Dr. Oliver, may prepared by saturating bibulous paper in solutions of potassio-mercuric iodide, of potassium ferrocyanide, and of citric acid. To use these papers the urine is acidified with one of the citric acid papers, and then either a potassio-mercuric iodide or a potassium ferrocyanide paper added.

The **quantitative** estimation of albumin is of considerable importance, but somewhat difficult to perform. Comparative tests are all that the clinician will usually find necessary. The easiest approximate method is to boil a given quantity of the urine in a test tube, add 2 or 3 drops of nitric acid, set aside for 12 hours, and note the volume occupied by the precipitated albumin. This is generally spoken of as **volume per cent., and has no relation to actual percentage**.

A more accurate method, and one sufficiently so for clinical purposes, is with Esbach's **albuminometer.** This consists of a graduated glass tube, shown in Fig. 71. To use the instrument, fill to U with urine, and to R with the test liquid. Close the tube by a rubber stopper, mix by agitation, and set aside for 24 hours. Each of the main divisions which the precipitate covers, represents 1 grm. of albumin in 1 liter of urine.

Test solution:	Picric acid, ...	10 grms.
	Citric acid, ...	20 grms.
	Water, ...	1000 grms.

FIG. 71



Densimetric Method.—Take the specific gravity as accurately as possible, noting the temperature. Coagulate the albumin, by boiling with the least amount of acetic acid that will completely do this. Filter from albumin. Bring the filtrate to the same temperature as before, and take the specific gravity again The difference in specific gravity degrees multiplied by 0.4 gives the grams in 100 c.c. of urine. Or, a difference of one degree in sp. gr. gives 0 400 grm. albumin in 100 c.c. of the urine. It will be seen, therefore, that the specific gravity should be very accurately taken with the picnometer.

Serum Globulin, or **paraglobulin,** is usually associated with serum albumin, from which it may be separated. It may be detected in the urine as follows: To a large volume of water in a beaker or urine glass let fall a few drops of albuminous urine If globulin be present, each drop as it falls will be followed by a milky train, which, when enough is added, forms an opalescent cloud in the water. The addition of acetic acid dissolves this cloud. This test depends upon the fact that globulin is soluble in a weak solution of sodium chloride, but on greatly diluting this solution, the globulin becomes insoluble, as in pure water. It is, therefore, precipitated by diluting the urine until the specific gravity is 1002 to 1003.

It may be precipitated by rendering the urine slightly alkaline with NH_4OH, filtering to separate the phosphates, and adding to the filtrate an equal volume of a saturated solution of ammonium sulphate. If a precipitate forms, it is globulin. It occurs with serum albumin, and rarely without it. It is most abundant in lardaceous kidney, in some cases of acute nephritis, and in the temporary albuminuria of disordered digestion.

Albumoses, or **Propeptones.**—To test for albumose it is best to first remove the albumin. This is best done by acidifying the urine with a few drops of acetic acid, and adding about one-third its volume of a strong solution of common salt, boiling, and filtering. Albumin and globulin are thus removed. The filtrate is allowed to cool, and any turbidity which separates on cooling, or after the further addition of the salt solution, and which disappears by heating to re-appear again on cooling, is albumose or propeptone. Or, after the removal of the albumin and globulin as above, the solution may be saturated with ammonium sulphate, when albumose, if present, will be precipitated. The only disease with which it appears to be associated is osteomalacia.

Peptone.—Peptone is not present in normal urine, but is occasionally found, either with or without albumin. Peptone differs from albumin and albumoses, in that it is not precipitated by tests Nos. 1, 2, 3, 7, and 8, but is precipitated by Nos. 4, 5, and 6, and by tannin, phospho-tungstic acid,* and Millon's reagent. When precipitated by tests 4, 5, and 6, it is dissolved when the solution is warmed, and separates again as it cools. Peptone gives with the biuret reaction, a rose-red color, while albumin gives a purple or blue.

Tests for Peptone.—These all require previous treatment of the urine. If albumin be present, it should first be removed, either by saturation with ammonium sulphate and filtration, or by the addition of acetic acid and potassium ferrocyanide and filtering. It is usually desirable to decolorize the urine by the addition of a solution of lead acetate as long as it produces a precipitate, and filtering. The test may now be applied to this filtrate. Phospho-tungstic acid, acidulated with acetic acid, added to this filtrate, will precipitate peptone, if present. But if it be present in small quantities, the cloudiness appears only after 5 to 10 minutes.

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* Phospho-tungstic acid is made by adding H_3PO_4 to a hot solution of sodium tungstate till decidedly acid. Cool, and render strongly acid with acetic acid. Filter after standing over night.

A less sensitive test than the above is made by floating the urine upon some Fehling's test solution. At the point of contact, a delicate rose-red zone will indicate peptone. When positive this test is valuable, but when negative it will not prove the absence of peptone.

The presence of peptone in the urine although not positively settled, is believed to be due in most cases to the disintegration of pus corpuscles somewhere in the body, and the absorption of the decomposition products. It is found in many of the acute fevers and in many acute inflammatory processes. It may serve to tell whether a pleuritic effusion is purulent or not, and to distinguish tubercular from epidemic cerebro-spinal meningitis, as the latter is usually attended with peptonuria, while the former is not.

Mucin.—Mucin is secreted by the healthy mucous membranes. It cannot be regarded, therefore, as abnormal in the urine until it is present in increased amount, and then it indicates an irritated or inflamed condition of the membranes of the urinary tract. It is not precipitated from its solutions by boiling, but is precipitated by alcohol, dilute mineral acids, acetic, picric, and citric acids. It is best detected by its forming a sediment on standing, which floats as a translucent cloud near the bottom of the containing vessel, but not upon it. It may also be detected by floating the urine upon a solution of citric or acetic acid, when just above the line of contact a somewhat indefinite zone or coagulum gradually makes its appearance. Albumin, when present, is not precipitated by these acids without the application of heat.

We may also precipitate mucin by the addition of about two parts of alcohol to one part of urine, when mucin and any albuminoid bodies present will precipitate. The precipitate may be filtered out, washed with alcohol, and the mucin dissolved out with warm water, when it may be precipitated from the filtrate again with alcohol or the dilute acids.

Accidental Albuminuria.—Whenever the urine contains blood, pus, or serous discharges it will of necessity contain albumin. **Fibrin** will be found when there are hemorrhages from the genito-urinary passages, and in intense or acute inflammations of the kidneys It also occurs in the urine of most cases of chyluria. It is readily recognized by its spontaneous coagulation, forming a thick, gelatinous, glairy mass, separating at the bottom of the containing vessel. The coagulum may be filtered out and its solubility determined. If insoluble in dilute alkalies and 10 per cent. NaCl solution, it is fibrin.

Blood.—The presence of **blood** may be detected most readily and certainly by the microscope, when the red blood corpuscles may readily be seen.

Chemically, blood-coloring matter can be detected by the use of the following test: Mix a small portion of the urine in a test tube with an equal volume of a mixture of freshly prepared tincture guaiacum and spirits of turpentine. The turpentine should previously have been exposed to the air for some time. If blood-coloring matter be present, the mixture assumes an indigo blue color, whose rapidity of formation and depth of color depend upon the amount of blood-coloring matter present. Pus frequently, if not always, gives the same test. Saliva and salts of iodine also give a blue color with this test, but the color due to these substances appears only after a considerable lapse of time, and is seldom likely to mislead. From the depth of the color of the urine, and the rapidity of the appearance of the blue color, one can judge of the relative amount of blood in solution. The spirits of turpentine used in this test may be replaced by a solution of peroxide of hydrogen, or a mixture of ether and H_2O_2 (ozonic ether).

Having determined that blood is present in the urine, it is a difficult matter to decide whether the albuminuria is due entirely to the albumin introduced with the blood, or whether it is a true albuminuria of renal or inflammatory origin. This will often depend upon other symptoms than those to be found in the urine. Dissolved blood-coloring matter is sometimes met with in the urine, when it is called **hemoglobinuria**. In hemoglobinuria, blood-corpuscles are not to be found with the microscope, while in **hæmaturia** the corpuscles are found. It occasionally happens that the urine rapidly becomes alkaline after being secreted, and the red blood-corpuscles are disintegrated and dissolved by the alkaline urine. The urine containing the dissolved corpuscles is then always alkaline, while the urine of true hemoglobinuria is usually acid. We may conveniently distinguish, then, two conditions: In one, the blood coloring matter is in solution, and in the other it is in suspension as blood-corpuscles. In the former case the coloring matter will not separate on standing, while in the latter, there will usually separate within a few hours, a more or less abundant red sediment. If the hemorrhage be a profuse one, especially if from the bladder or ureters, the blood will almost all of it settle to the bottom of the containing vessel, and leave a clear yellow, almost normal-looking urine above; while if the hemorrhage be a gradual oozing in acute inflammation of the kidney, the coloring matter will remain in suspension and the liquid retain its color for many days.

If we add an alkali to urine containing blood, the earthy phosphates are precipitated, carrying down with them the blood-coloring matter and forming a blood red deposit. By the application of heat the sediment deposits more rapidly. If the urine is already alkaline, and the phosphates have separated out, we can produce a precipitate for the purpose of carrying down the blood-coloring matter, by the addition of a few drops of a solution of $MgSO_4$. **Hæmin crystals** may be prepared from this precipitate, by spreading a small portion of it upon a glass slide and treating it with a crystal of common salt and a drop or two of glacial acetic acid, covering with a cover glass, warming it gently, and examining, after a few hours, with the microscope. The crystals appear as small, oblique plates of a dark red or brown color. They are easily recognizable by a good one quarter inch lens.

Pus.—If the urine contains **pus** it will always be turbid to the naked eye, and rapidly deposit a white or greenish-white sediment. The clear solution will be found to contain albumin and globulin. The application of heat to the sediment does not dissipate it, as it does the sediment of urates. Neither is it dissolved by diluted acids, as is the somewhat similar looking precipitate of the earthy phosphates. A whitish sediment, therefore, which is insoluble by heat or diluted acids, and which dissolves in strongly alkaline solutions, giving a gelatinous, ropy liquid, is probably pus (Donné's test). When pus is treated with a solution of hydrogen peroxide it undergoes rapid effervescence. This is a valuable test for pus in the urine or in other fluids. The microscope is a more certain test for pus Having detected pus in the urine, it is sometimes very difficult to determine whether the albuminuria accompanying it is accidental, *i. e.*, whether the albumin is derived from the pus, or whether there is a true albuminuria due to some disease of the kidney. The symptoms of the patient will, in many cases, assist in determining, though not always.

Sugar.—It has been claimed by many that glucose occurs in normal urine, and it has been disputed by equally good authority. The most delicate tests do detect glucose in most urines otherwise normal, though not in all. Suffice it to say that the usual tests and those here mentioned, except Molisch's, will not detect this substance in normal urine. Its appearance, then, in sufficient quantities to be detected by any of them must be regarded as abnormal.

When glucose occurs in the urine in an appreciable amount, it is known as **glycosuria**. When its occurrence persists for a considerable time and in considerable amount, and is attended with an increased amount of a light-colored urine, generally of a high specific gravity, it is pathological, and the disease is known as **diabetes mellitus**. The specific gravity is some guide to the detection of diabetes mellitus, but the specific gravity alone is not conclusive. A high specific gravity with a large quantity of light-colored urine, is strong presumptive evidence of diabetes mellitus. The finding of sugar in such a case is confirmatory. The detection of sugar in the urine is a comparatively simple process.

Tests for Glucose.—Trommer's Test.—To 4 or 5 c. c. of urine in a test-tube, add one-half its volume of liquor sodæ or liquor potassæ, and 1 or 2 drops of a solution of $CuSO_4$ (1 to 10). If sugar be present a clear, deep blue color is obtained. If an excess of copper sulphate be added, a clear solution may not be obtained, and will, in this way, disturb the test. The solution is now to be heated almost to boiling, but it is better not to boil. If sugar be present, at first a greenish, and then a yellowish turbidity forms, which rapidly changes to a reddish-yellow color and precipitates red cuprous oxide. A flocculent precipitate of the earthy phosphates always forms on adding the alkali, and must not be mistaken for suboxide of copper. Urine containing an abundance of uric acid, the xanthine bases, and mucus, and other substances found in some urines, will decolorize the blue solution, but there will be no red precipitate. In fever urines, this decolorization without precipitation, interferes greatly with the employment of this test. It is, therefore, not to be relied upon in doubtful cases.

To eliminate this source of trouble with the copper test, it is best to use a solution of the acetate of copper, or sodium acetate added to the sulphate, to precipitate the uric acid, xanthine, hypoxanthine, and the most of the creatinine and phosphates.

From 7 to 8 c. c. of the urine are heated to boiling, in a test tube, and without filtering from any precipitate that may form; add 1 c. c. of the copper sulphate solution, then, when partially cooled, 1 to 2 c. c. of a saturated solution of sodium acetate, having a slight acid reaction, and filter. To the filtrate, which should have a greenish-blue color, add the alkali or, better, the alkaline tartrate solution used to make Fehling's solution, and boil for 15 to 20 seconds. Thus modified, the copper test is much more reliable.

2. Other Forms of the Copper Test.—Haines' solution is made by dissolving copper sulphate in a mixture of equal quantities of glycerin and water. This solution may be used in larger quantities than the aqueous solution of copper used in Trommer's test, and some of the difficulties of that test overcome. The decolorizing effect of normal urine is not sufficient to decolorize a large amount of copper solution By adding a considerable amount of Haines' solution before heating, this error is partially eliminated. **Fehling's solution** is sometimes employed as a qualitative test, but usually only as a quantitative test; Haines' solution has all the advantages of Fehling's, with the additional advantage that it keeps well.

3. **Bismuth Test.**—To a few c c. of the urine in a test-tube, add an equal volume of sodium hydroxide, and then a fragment of bismuth subnitrate; mix well and boil for three to five minutes. If sugar be present, black metallic bismuth will be deposited as a sediment. If the quantity of sugar be small, only a part of the bismuth will be reduced, and the precipitate will appear gray. Albumin must be removed before this test is applied, or it will be decomposed by boiling with the alkali, forming the sulphide of bismuth, which will give a black precipitate.

4. A better form of this test is as follows: A solution is made of bismuth subnitrate, 2 grms.; Rochelle salt, 4 grms ; sodium hydroxide, 8 grms.; and distilled water, 100 c. c. The urine is heated to boiling, and a few drops of this alkaline solution of bismuth added, and on continuing the boiling, if sugar be present, the mixture turns black As in the previous test, albumin must be absent before this test is applied. This reagent is exceedingly delicate, and it is claimed to detect .025 per cent. of glucose.

5. **Picric Acid Test.**—To about 5 c. c. of urine add one-half as much of picric acid solution (as in testing for albumin), and then 2 c. c. of liquor potassæ or liquor sodæ, and boil. If sugar is present, a dark mahogany-red color is developed. If no sugar is present, a dark hue is developed before boiling, but not the dark color above described. If albumin is present, a turbidity will form on the addition of the picric acid, but it does not interfere with the test.

6. **Moore's Test.**—Add to the suspected urine, one-half its volume of liquor sodæ, and boil. If sugar is present, a dark-yellow, brown, or chocolate color is produced. The depth of color is proportional to the amount of sugar present.

7. **Indigo-carmine Test.—Reagent:** Mix one part of indigo-carmine, or of dried commercial extract of indigo, with 30 parts of pure dry sodium carbonate. To 5 c. c. of the sus-

pected urine, add enough of the above powder to give a transparent, blue solution, and heat to boiling. If sugar is present, the solution changes to violet, cherry-red, and finally yellow. On agitation, these colors appear in the reversed order.

Instead of extract of indigo, a solution of sulphate of indigo with an excess of sodium carbonate may be employed. None of the ordinary constituents of the urine affect this test. while all the acids of the urine affect Fehling's solution; and many other substances which reduce the copper test do not affect the indigo-carmine test. In careful hands it is very much to be recommended as a sensitive and reliable test for glucose in the urine.

8. **Phenylhydrazin Test.**—For the details of this test see **glucose** in Part V. of this book.

9. **Alphanapthol Test.—Molisch's Test.**—To 1 c. c. of the urine add 2 c. c. of a saturated solution of *a*-naphthol, and after mixing, add an excess of H_2SO_4. If sugar be present, a deep violet color is developed. On dilution with water a blue precipitate occurs, which is soluble in alcohol, ether, and potassium hydroxide, to give a yellow solution. If, instead of naphthol, we use thymol or menthol, a deep red color is produced, which gives a carmine-red, flocculent precipitate on dilution, which dissolves as above with the formation of a yellow solution. This test is exceedingly delicate, and reacts with most sugars and glucosides. Urea, indican, creatinin, xanthin, uric acid, hippuric acid, phenol, pyrocatechin give negative results. As normal urine generally responds to this test, Molisch concludes that it contains sugar.

The Quantitative Estimation of Glucose.—This is generally made with Fehling's solution. This solution is best prepared in two parts, which are kept separately, as the completed solution does not keep well. These solutions are prepared as follows: No. 1. 34.639 grms. of pure recrystallized copper sulphate are dissolved in distilled water, and made up to exactly 500 c. c. No. 2. 175 grms. of chrystallized Rochelle salt and 60 grms. of sodium hydroxide, are dissolved in distilled water, and made up to exactly 500 c. c. When needed for use, exactly equal volumes of these two solutions are mixed. The solution will be of such strength that 10 c. c. are decolorized by .050 grm of glucose or diabetic sugar.

The process is conducted as follows: 10 c. c. of Fehling's solution are measured out into a beaker or porcelain basin, diluted with about 40 c. c. of water, and brought to the boiling point. The urine is delivered into this blue solution from a burette, until the blue color is just discharged. The amount of urine added will then be read off from the burette, and this amount will contain .050 grm. of sugar. From this it will be easy to calculate the quantity contained in 1000 c. c. or a liter. If the urine contains a considerable quantity of sugar, it will be necessary to dilute it with four volumes of water before beginning the titration. It is always somewhat difficult to determine the exact disappearance of the blue color, owing to the presence in the solution of the precipitated suboxide of copper. This difficulty may be overcome by the addition of some substance that will prevent the precipitation of the cuprous oxide as NH_4OH,-KCy or $K_4Fe\ (CN)_6$.

The author's method is as follows: Ten c. c. of Fehling's solution are measured out into a suitable flask. To this 10 c. c. of a freshly prepared 10 per cent. solution of potassium ferrocyanide are added, and about 30 c. c. of water. The mixture is heated on a water-bath, and the urine, previously diluted with water, if it contains much sugar, is run in from a burette, drop by drop, until the blue color just disappears, which can readily be seen, as the solution remains clear to the end of the reaction. The addition of the slightest excess of sugar shows itself by the solution becoming quickly brown. By careful comparative tests the author has found this method to be accurate, reliable, and rapid, provided the solution be not boiled during the reduction. The best temperature for the process was found to be between 80° and 90° C. (176° to 194° F.).

Estimation by the Polariscope.—This is the most convenient and quickest method for the determination of glucose, when the quantity exceeds 1 per cent, and when all the appliances are at hand, which is seldom the case except in well-equipped laboratories. The method, briefly, is as follows: The suspected urine, freed from albumin, is treated with a solution of basic lead acetate, in the proportion of 1 to 10 of the urine, and filtered. The tube of the polariscope is filled with this fluid, when it is placed in position and the rotation determined.

The readings must be increased by one-tenth (allowance for the lead acetate solution).

The specific rotatory power of glucose is $+ 52.5°$.

The weight of the sugar in the solution will be given by the formula: $W = \frac{a}{52.5 \times l}$; in which a = observed rotation, l the length of the tube in decimeters, and W the weight of sugar in 1 c. c. of the solution.

Suppose, in a given case, the rotation observed was 4°, after allowing for the lead solution, and the length of the observation tube was two decimeters. We will then have $W = \frac{4}{52.5 \times 2}$, or $\frac{2}{52.5} = .038$ grm. in 1 c.c. of urine, or 3.8 per cent.

As lævulose sometimes occurs with glucose in cases of diabetes, and as it will rotate the plane of polarized light to the left instead of to the right, and, in fact, as there are a number of substances likely to occur in the urine which rotate the plane of polarized light, this method of determining sugar is not always free from error.

Lactose, or **milk sugar**, occurs in the urine of nursing women or of women soon after weaning. Its recognition requires first its separation from the fluid.

Dextrin has been found in the urine of diabetics, where it seems to take the place of glucose. Other carbohydrates found rarely in the urine are inosite, maltose, and animal gum.

Acetonuria.—Normal urine contains traces of acetone, but it occurs in excessive quantities as a pathological condition. It is found in many of the fevers, certain forms of cancer, in starvation, and in certain nervous troubles accompanying diabetes. The commonest of these is febrile acetonuria. Its appearance in diabetes indicates an advanced stage of the disease.

Detection.—Four or five c.c. of the urine are treated with a few drops of a freshly made solution of sodium nitroprusside and with a strong solution of NH_4OH. The red color produced, which appears in from 5 to 10 minutes if acetone be present, gives place to a purple or violet color, on the addition of acetic acid. For a more accurate test it is necessary to distil the urine and apply the following test to the distillate:—

Lieben's Test.—To several c.c. of the distillate add a few drops of a solution of iodine in potassium iodide, and then a solution of KOH. If merely a trace of acetone be present, a precipitate of iodoform crystals is deposited. This test is reliable and delicate in the absence of lactic acid and alcohol, but if NH_4OH be used for the KOH, alcohol will not form iodoform while the acetone will do so.

Diacetic Acid appears in the urine of diabetics and certain fevers, and is always an abnormal constituent. It is most common in the contagious fevers of childhood, and in such cases has little significance; but in adults it is a grave symptom, as it usually precedes the advent of coma. It usually occurs together with acetone, and in the presence of ferric chloride produces a wine-red color, which is not entirely characteristic, because other substances produce the same color. The following process will serve for its detection: A fairly strong solution of ferric chloride is cautiously added to the urine, and if a phosphate precipitates, this is removed by filtration, and more Fe_2Cl_6 added to the filtrate. If a red color appears, it is divided into two portions. One portion is boiled, whilst the other is treated with H_2SO_4, and extracted by shaking with ether. If the urine which has been boiled shows little or no change, while the Fe_2Cl_6 reaction in the ethereal extract is not evident after twenty-four hours, and if at the same time it is found to be rich in acetone, diaceturia may be inferred. Usually, if the reaction with ferric chloride is very marked, and no acetone is discovered to be present, we may conclude that diacetic acid is present, without the above somewhat tedious test. The urine for this test must be fresh, as diacetic acid is rapidly converted into acetone on standing. Acetone is an oxidation product of diacetic acid. If the quantity of acetone be large it may cause toxic symptoms.

Oxybutyric Acid is found in the blood of diabetic patients, and its oxidation produces diacetic acid. The relation of these three bodies is then oxybutyric acid, diacetic acid, and acetone, in the order named.

Lipaciduria is a term which has been applied to the condition in which volatile fatty acids are found in the urine. These occur in traces normally, especially formic, acetic, and butyric acids. As a symptom of disease, however, they are often present in quantity; thus, in the urine of fevers, in certain diseases of the liver, and in diabetes, formic, acetic, propionic, and butyric acids, have been detected. For their detection the urine is distilled with phosphoric acid, and the test applied to the distillate. For simpler tests we may apply the following: Acetic acid may be detected by the odor of acetic ether when the distillate is warmed with alcohol and sulphuric acid. Ferric chloride gives a red tint, which disappears on boiling if acetic acid is present. Formic acid gives a white precipitate with silver nitrate, which blackens on warming.

Fat.—Fat occasionally occurs in the urine, and gives to it a more or less turbid appearance, which clears on shaking the solution with ether. On separating and evaporating the ether, the fat globules remain behind. In chyluria we have an opacity due to fat and albuminous substances in imperfect solution. In some cases the appearance of this urine is intermittent, appearing only at certain times of the day, in others it is constant. In some cases chylous urine deposits a spontaneous clot of fibrin, while in others it does not. The fat may be separated by extraction with ether, but the turbidity may still remain. In some cases, however, the turbidity disappears with the extraction of the fat.

Detection.—Its detection is usually sufficiently easy from the milky-white color and the separation of the fat on standing. Microscopically, the fat globules can be detected in some cases, but in others the microscope fails to reveal them The author has seen a case where they were not visible with a one-sixteenth inch objective

Bile.—Urine containing bile usually has an abnormal color—either a brilliant yellow, a greenish-yellow, or brown. When the bile is abundantly present, the froth or foam produced on shaking the urine is quite permanent, and is more or less colored. A piece of filter paper or linen moistened with such urine retains the yellow color on drying

Gmelin's Test.—Upon 1 or 2 c. c. of a partially decomposed yellow nitric acid, in a test tube, carefully float 4 or 5 c. c. of the suspected urine. If bile coloring matters be present, successive colors will appear in the urine, beginning with green, then passing through blue, violet, red and yellow, the green appearing at the top and the others in the order named downward. The green color is always present when bile is present, but the reddish velvet color must not always be taken for evidence of bile, as the normal coloring matters may produce such a coloration.

If the decomposed nitric acid, or nitrous acid, be not at hand, it may readily be prepared by adding a fragment of zinc to ordinary pure nitric acid. This test may also be applied as follows: The urine may be mixed with a concentrated solution of sodium nitrate, and the mixture floated upon sulphuric acid, when a play of colors will be obtained as before.

Ultzmann's Test.—To 5 c. c. of the urine add 2 c. c. of a strong solution of KOH (1 to 3); mix well and add an excess of pure hydrochloric acid. The mixture will assume an emerald-green color if bile-coloring matters be present.

Tincture of Iodine Test.—Upon the surface of the urine in a test tube float a few drops of tincture of iodine. At the line of contact of the two fluids, there appears after a few minutes a beautiful emerald-green zone when biliary coloring matters are present. This test seems to be delicate and reliable.

Biliary Acids.—While the acids usually occur in the urine of jaundiced patients, along with the coloring matters, their detection is not so easy. We may use the following test: Evaporate the liquid to dryness, and with the residue, consisting of biliary salts, make a solution in alcohol, and then, after evaporating the alcohol, apply Vettenkofer's test (see biliary acids) to a solution of the residue in water. **Dr. Oliver's peptone test** is, however, applicable to urine. The reagent is prepared as follows: Pulverized peptone (Savory and Moore) 2 grms.; salicylic acid, 0.250 grm.; acetic acid, 2 c c.; distilled water, sufficient to make 250 c. c. The urine, rendered perfectly clear by filtration, is rendered acid and diluted until the specific gravity is 1008. One c. c. of this urine is run into about 4 c. c. of the above test solution If biliary salts are present, a distinct milkiness promptly appears, but it becomes more intense in five minutes. Albumin, if present, should be separated before the application of this test. The test is very delicate and apparently reliable.

Diazo-reaction.—This reaction is one that is obtained in the urine of persons suffering from certain specific fevers, especially typhoid fever, measles, septicæmia, and in some cases of phthisis. The reagent is made as follows: One grm. of the sulphanilic acid is dissolved in a mixture of 350 c.c. of water and

15 c.c. of hydrochloric acid. A second solution is made by dissolving .5 grm. of sodium nitrite in 100 c.c. of water. Five c.c. of urine are mixed with an equal volume of sulphanilic acid solution, and then with 3 or 4 drops of the sodium nitrite solution, and, finally, 10 drops of ammonia water. Normal urine shows with this test a yellow or orange color with the precipitation of phosphates. In certain of the above named diseases, especially in typhoid, the urine gradually assumes a carmine-red color. The froth produced on agitation is also distinctly red, and the precipitated phosphates show a green or violet color. Many phenol derivatives give a similar color reaction with the above test, and many lead to erroneous conclusions. According to Ehrlich, this reaction is characteristic of the urine in typhoid, measles, and acute tuberculosis. Others deny the value of the test, the difference being possibly due to the interference of phenol derivatives.

Ferments Found in the Urine.—Pepsin, trypsin, and a diastasic ferment have been found in the urine in addition to the organized ferments of lactic, butyric, and acetic acids, and urea. The pepsin ferment of the urine is said to be absent in the urine of typhoid fever, carcinoma of the stomach, and, according to some, in nephritis.

Detection.—Pepsin is best detected by Sahli's method. A little pure fibrin is placed in the urine and set aside for several hours. It is then removed, placed in diluted HCl (.2 per cent.), and the mixture kept at a temperature of from 30° to 40° C. (86° to 104° F.). Any pepsin present in the urine is taken up by the fibrin, and the latter is slowly digested in the acid fluid.

The diastasic ferment is detected in the usual matter by its effect upon starch mucilage. The milk-curdling ferment has occasianally been found in the urine. See also Organized Ferments.

Ptomaines have been found in healthy urines as well as in morbid urines. In most fevers, especially in the specific and contagious fevers, the urine contains certain poisonous alkaloids. These can be detected by first acidifying the urine and filtering from any mucus present, and then precipitating with the double iodide of potassium and mercury. The precipitate, which contains the alkaloids, is distinguished from albumin or other substances by its solubility in alcohol at a gentle heat.

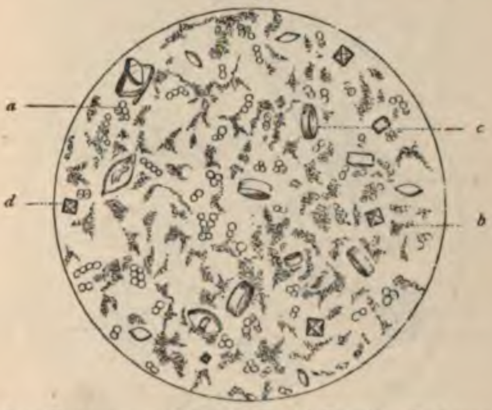
The Diamins of the urine may be precipitated, as benzoyl compounds by the action of benzoyl chloride, and caustic potash. By this means cadaverin, putrescin, and other diamins have been detected in the urine of vesical catarrh. Normal urine is said to be free from these bodies.

URINARY DEPOSITS OR SEDIMENTS.

Normal urine is clear, but on standing it will usually deposit more or less sediment. Urine that is turbid when passed will usually deposit a sediment which may contain mucus, pus, earthy phosphates, acid urate of sodium, or an abundance of epithelium from the kidney, ureters, or bladder. A turbidity which appears within a few hours after the urine is voided, is most likely to be due to acid urates, the oxalate of lime, or the earthy phosphates. When such a deposit is to be examined, a few ounces of the urine are set aside in a cylinder or tall vessel to allow the sediment to accumulate. The sediment may be removed from the solution by means of a pipette, or narrow glass tube, by holding the finger upon the upper end, until it is depressed to the bottom of the glass, and then on removing the finger for an instant, the sediment will be drawn up into the tube, when it may be removed for examination. To the crystalline deposits belong uric acid, urates, calcium oxalate, the phosphates or carbonates of magnesium and calcium, cystin, hippuric acid, leucin, tyrosin, etc. Organized deposits may include mucus, blood, pus, casts, epithelium, fungi, and bacteria.

The chemical examination of the deposits should be preceded by a microscopical examination. In fact, with a little experience, the microscopical examination will usually obivate the necessity of a chemical examination. Most of the unorganized and crystalline sediments may be easily recognized by microscopical as well as chemical means.

FIG. 72.



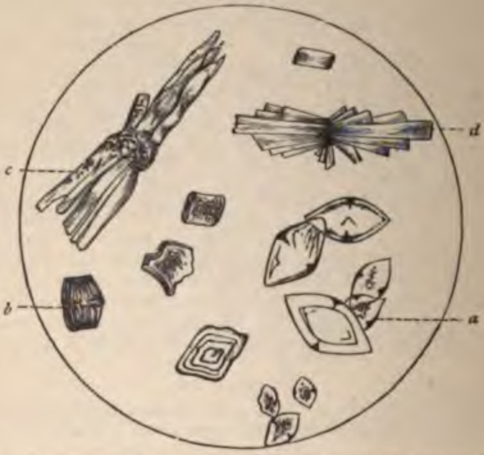
DEPOSIT IN "ACID FERMENTATION" OF URINE. (*a*) FUNGUS; (*b*) AMORPHOUS SODIUM URATE; (*c*) URIC ACID; (*d*) CALCIUM OXALATE.

Crystalline Deposits.—Uric acid occurs in crystals deeply stained a brownish-yellow to a light lemon yellow color, differing much in form and size. They are sometimes large, and when grouped together, as at (*d*), Fig. 73, are large enough to be seen with the naked eye. They dissolve when warmed with NaOH solution. The most characteristic are those shown in Figs. 72 and 73.

Acid Urates.—Amorphous urates consist principally of acid sodium urate. See Fig. 72. The deposit is amorphous unless a very high magnifying power is employed. Then it is seen to be made up of minute globular particles of a yellow, red, or brown color. This sediment separates only from acid urines. It dissolves to a clear solution on adding a solution of NaOH or KOH, or when heated.

For the purpose of testing the solubility of the sediment under the microscope, it will be found convenient to place a drop or two of the solvent on the slide at one side of the cover glass, and put on the other side a piece of bibulous paper. In this way the fluid is drawn under the cover glass on the one side and removed at the other, the old liquid being replaced by the new. In this way the action of the reagent upon urinary sediments may be readily observed.

FIG. 73.

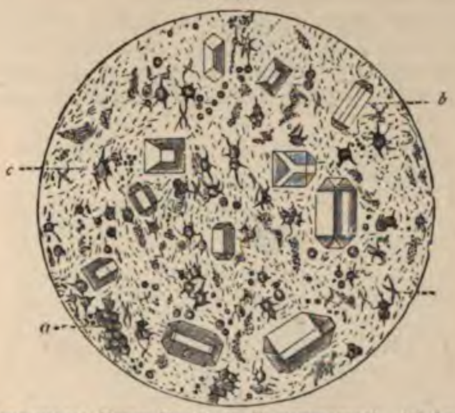


URIC ACID. (*a*) RHOMBIC TABLES (WHETSTONE FORM); (*b*) BARREL FORM; (*c*) SHEAVES; (*d*) ROSETTES OF WHETSTONE CRYSTALS.

Acid sodium urate somethimes crystallizes during the acid fermentation, in the form of larger spheres made up of elongated crystals. They appear under the microscope as yellowish or brown, frequently almost opaque spheres, with one or more spicules. When the urine becomes alkaline from fermentation, the amorphous urates are gradually converted into ammonium urate, which has the appearance seen in Fig. 74.

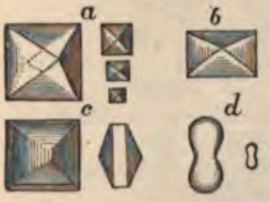
Calcium Oxalate occurs as a sediment in transparent, strongly refracting, regular octahedrons, which are readily soluble in HCl, but insoluble in acetic acid. They frequently accompany uric acid crystals, and deposit during the acid fermentation, as shown in Fig. 72. They are frequently called envelope-shaped crystals from the fancied resemblance to the reverse side of an envelope. They are usually of very small size, and occasionally appear in the form of dumb-bells. (Figs. 75 and 76.) A few isolated crystals of calcium oxalate have no clinical significance. They greatly increase after eating such vegetables as tomatoes, fresh beans, beet root, asparagus, etc. **Oxaluria** is a disease in which an unusually large proportion

FIG. 74.



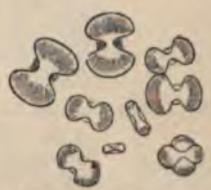
Deposit in Ammoniacal Urine (Alkaline Fermentation). (*a*) Acid Ammonium Urate; (*b*) Ammonio-magnesium Phosphate; (*c*) Bacterium Ureæ.

FIG. 75.



Oxalate of Lime. (*a*) Octahedra; (*b*) Basal Plane of an Octahedron forming a Rectangle; (*c*) Compound Forms; (*d*) Dumb-bells.

FIG. 76.

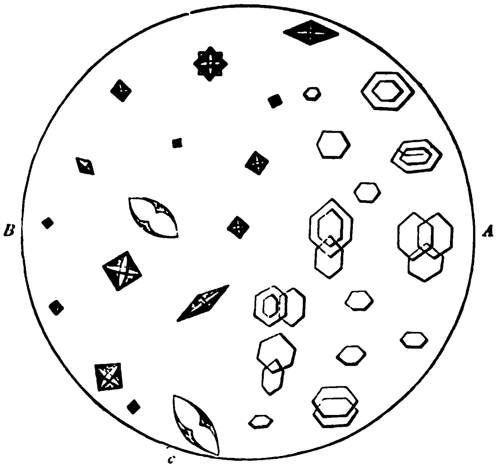


Perfect Dumb-bell Crystals of Oxalate of Lime.

of oxalate of lime is found in the urine, together with certain well-marked nervous symptoms. It is usually here associated with an excessive amount of mucus and phosphates.

Triple Phosphate. — **Ammonium magnesium phosphate** occurs as a sediment in neutral or in alkaline urine. The crystals are large, transparent, highly refracting prisms, usually in the form seen in Fig. 79. Occasionally it occurs in the form of feathery crystals or star-shaped groups. They are never colored. They frequently attain a size sufficient to render them visible to the naked eye, especially in a strong light.

Fig. 77.



A, Crystals of Cystin; *B*, Oxalate of Lime; (*c*) Hour-glass Forms of *B*.

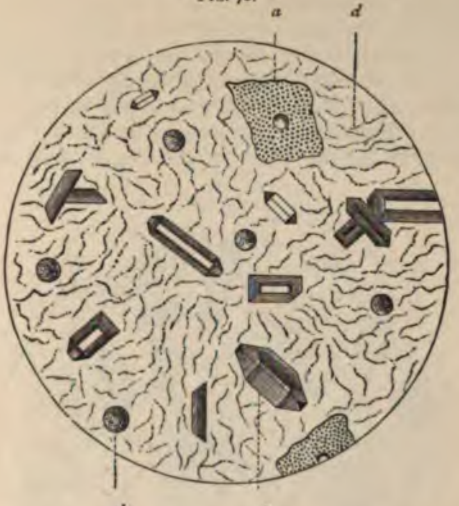
Magnesium Phosphate.—Is deposited occasionally in concentrated urines of feebly alkaline reaction.

Calcium Phosphate crystals appear as pointed, wedge-shaped prisms, either singly or in clusters. They are dissolved by acetic or hydrochloric acid.

Calcium Sulphate is rarely present as a urinary sediment. It occurs in the form of long, colorless needles or prisms, or in elongated tables with abrupt extremities.

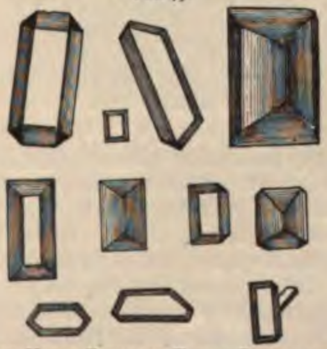
Calcium Carbonate occasionally occurs in the urine as an amorphous deposit, but on higher magnification it is seen to be made up of minute spherical granules. (See Fig. 82.)

FIG. 78.



DEPOSIT FROM A CASE OF INFLAMED BLADDER (AMMONIACAL FERMENTATION). (*a*) DETACHED EPITHELIUM; (*b*) PUS CORPUSCLES; (*c*) TRIPLE PHOSPHATE; (*d*) MICRO-ORGANISMS.

FIG. 79.



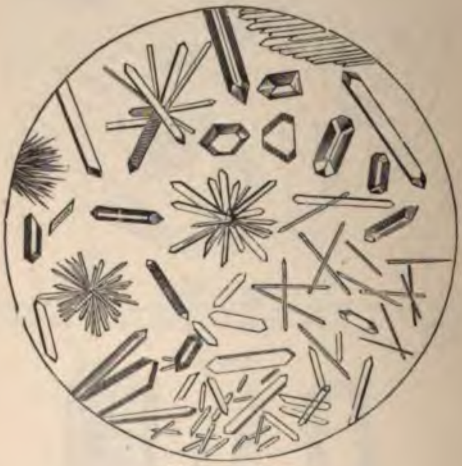
THE MORE USUAL FORMS OF TRIPLE PHOSPHATE. × 300.

Hippuric Acid occurs occasionally as a sediment in the urine in the form of four-sided prisms, either occurring separately or in groups. They are soluble in ammonia, insoluble in HCl. It occurs especially after the administration of benzoic acid, and the eating of certain fruits, as cranberries, bilberries, etc. It is of no diagnostic importance.

Cystin.—The crystals of this body appear as regular hexagonal plates, superimposed or contiguous to one another (see Fig. 77). They are insoluble in acetic acid, but soluble in ammonia. It is sometimes also found in solution in the urine.

Leucin and **Tyrosin** always occur together. Tyrosin occurs in the sediment in the form of sheaves of very fine crystals.

FIG. 80.



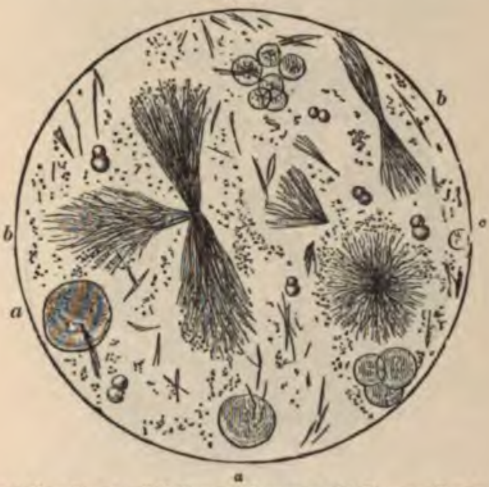
HIPPURIC ACID.

Leucin, commonly associated with tyrosin, is more soluble, but occurs to some extent in the sediment in the form of small spheres, not unlike oil globules, which in a good light are seen to be marked with radiating striæ. When quite pure, leucin crystallizes in delicate plates, but as it separates from the urine it usually forms little spheres (see Fig 81). Tyrosin has been found in the urine, together with leucin, in phosphorous poisoning, in acute yellow atrophy of the liver, in leukæmia, and in some of the infectious diseases.

Fat is deposited in the form of strongly refracting globules of varying size, and readily soluble in ether. It may be present in the urine in small quantities after the fracture of bones, and in some chronic cases of Bright's disease attended with fatty degeneration. In chyluria it occurs in greater abundance.

Indigo occurs in the urine as concretions and amorphous fragments, and also in the form of blue crystals and fine blue needles cohering together in clusters. The crystals of indigo are not rare in decomposing and fermenting urines in which it results from the decomposition of the indoxyl sulphates. They occur more especially in the urine of hepatic abscess and cirrhosis of the liver.

FIG. 81.



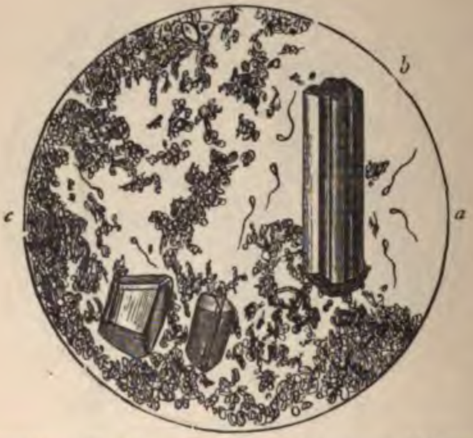
(*a a*) LEU BALLS; (*b b*) TYROSIN SHEAVES; (*c*) DOUBLE BALLS OF AMMONIUM URATE.

Urinary Concretions of considerable size are occasionally to be seen in urine, with the naked eye. They consist, for the most part, of urates, or urates with uric acid. Their recognition is important in the diagnosis of renal colic. Their color is usually red or brown when composed of uric acid or acid urates. Phosphatic concretions of larger size occur more rarely. They are light colored. Other concretions are occasionally met with.

Foreign Bodies occur in the urine from accidental causes, or from negligence in collecting the specimen. We may mention fungi, yeast cells, microörganisms, fat globules, fibers of silk, linen, wool, feathers, wood, starch, etc. Bodies of this kind will be seen in almost every specimen examined. They will not cause any confusion after a little practice, as but one of the kind will usually be found, and they are so different from any of the sediments that mistakes will hardly be made. Fragments of tumors, as sarcoma, carcinoma, etc., may occasionally be found, and their import is self-evident.

Organized Deposits.—Mucous corpuscles are seen as round, finely glanular cells, somewhat larger than blood corpuscles, and containing from 3 to 5 nuclei. They cannot be distinguished from the colorless blood corpuscles. (See Fig. 86.) **Pus corpuscles** resemble the mucous corpuscles in their appearance. Water causes these corpuscles to swell, the nuclei becoming more distinct, and the outline gradually disappearing. Acetic acid produces a similar change, but more rapidly. Solutions of KOH, NaOH, and NH_4OH disintegrate these corpuscles, destroying the cells and granules; the nuclei are the last to disappear. In alkaline urines, therefore, the mucous and pus corpuscles, if present, rapidly undergo disintegration.

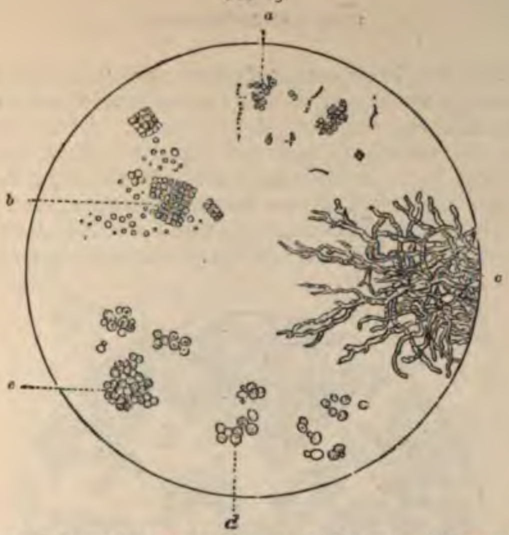
FIG. 82.



(*a*) SPERMATOZOA; (*b*) AMORPHOUS CALCIUM CARBONATE; (*c*) CRYSTALLINE MAGNESIUM PHOSPHATE.

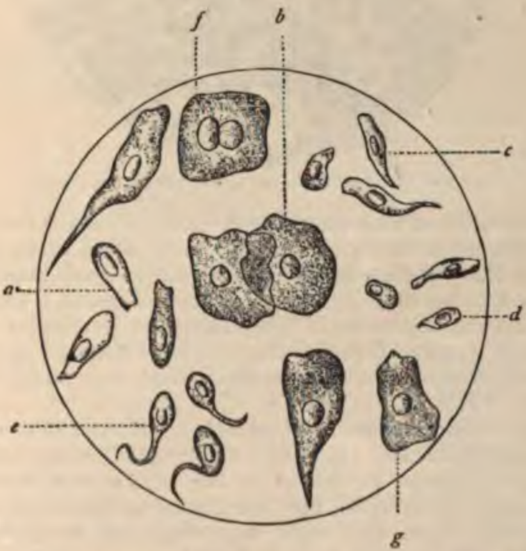
Epithelium cells of a variety of shapes are found in normal urine. Those from the convoluted portion of the tubules are polygonal in shape, but on remaining for some time in the urine, they absorb water and become globular. They are a little larger than pus corpuscles, and may be distinguished from the latter by having one large, distinct nucleus. The epithelium cells of the loop

Fig. 83.



(*a*) Micrococci in Short Chains and Groups; (*b*) Sarcinæ; (*c*) Fungi from Acid Fermentation; (*d*) Yeast Cells from Diabetic Urine; (*e*) Mycelium of a Fungus.

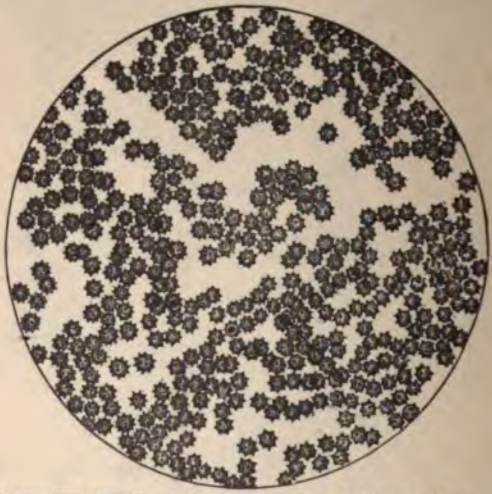
Fig. 84.



(*a*) Epithelium from the Male Urethra; (*b*) Vagina; (*c*) Prostate; (*d*) Cowper's Glands; (*e*) Littre's Glands; (*f*) Female Urethra; (*g*) Bladder.

of Henlé and the larger collecting tubes are columnar in shape. Those from the ureter, pelvis, and urethra are elongated and conical, containing one nucleus near the centre. Large, flat epithelium cells are obtained from the bladder, vagina, and female urethra. (Fig. 84.) In chronic cystitis, after the large, flat, irregular cells have been shed off, we may have smaller, rounded cells, having a large nucleus in comparison with the remainder of the cell. Old cells, slowly proliferated and desquamated, have a smaller nucleus in comparison with the rest of the cell. This is of importance in the diagnosis of new growths likely to be found in the bladder.

FIG. 85.



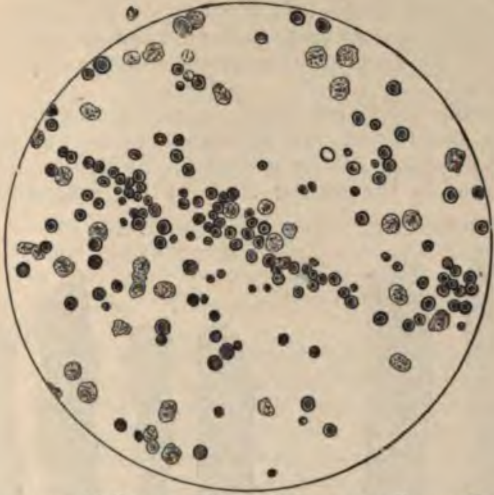
CRENATED RED BLOOD CORPUSCLES IN THE URINE. × 350.

Blood Corpuscles in the urine appear as small, round, disc-shaped corpuscles of a light straw or red color, and when seen on edge appear bi-concave. They are prone to changes in form and size on standing for some hours. They undergo decomposition in alkaline urines, change their form, and finally become invisible. (Figs. 85 and 86.)

Casts.—Casts are fibrinous moulds of the uriniferous tubules and frequently contain blood or pus corpuscles, epithelium cells, crystals or oil drops, imbedded in the substance of which they are composed, from which they are named epithelial casts, blood casts, granular casts, fatty casts, waxy casts, and hyaline casts.

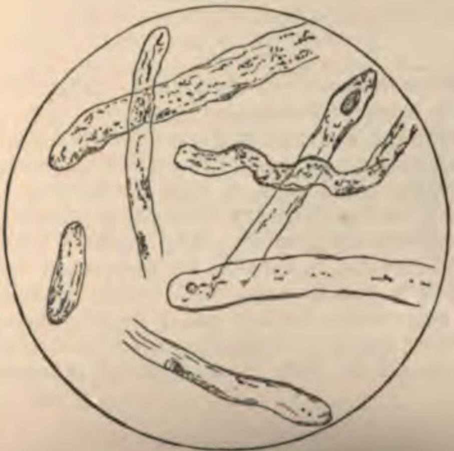
Hyaline Casts are perfectly clear, transparent cylinders, without markings, having nearly the same refractive index as the urine, and consequently are not readily seen, especially in a strong light. (Fig. 87.) They are more readily seen with oblique illumination, or by adding a drop of a solution of eosin or fuchsin, to the urine while the sediment is forming. They are characteristic of the very earliest and the recovering stages of ne-

FIG. 86.



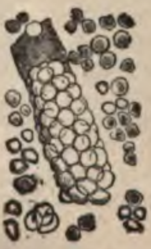
COLORED AND (*a*) COLORLESS BLOOD CORPUSCLES OF VARIOUS FORMS.

FIG. 87.



HYALINE CAST.

FIG. 88.



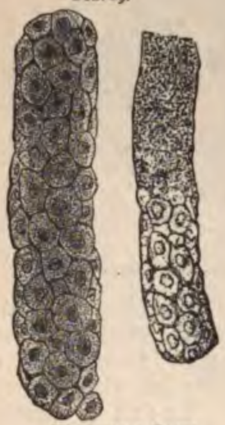
BLOOD CAST.

phritis, and are also found in congestion of the kidney, or in simple irritative catarrh of the tubules.

Blood Casts contain blood corpuscles imbedded in them, and indicate an acute inflammation of the kidney and the escape of blood corpuscles from the circulation into the tubules. (See Fig. 88.) They are characteristic of the very acute stages of nephritis.

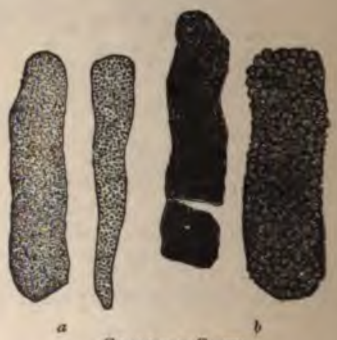
Epithelial Casts are those in whose surfaces epithelium cells from the tubules are imbedded. (See Fig. 89.) They indicate a shedding of the epithelium lining the tubules, and usually occur in the second stage of the inflammation, *i. e.*, when the inflammation has loosened the epithelium. They will usually be found only in acute nephritis.

Fig. 89.



Epithelial Casts.

Fig. 90.



Granular Casts.

Granular Casts are those containing granules, either small or large. The granular matter may come from either the disintegration of the epithelium, blood cells, or from the material of the cast itself. They are frequently spoken of as finely granular, moderately granular, and coarsely granular; the amount of granular matter giving an idea of the amount of the destructive disintegration taking place in the kidney. The dense, coarsely granular varieties, as represented by Fig. 90, *b*, are more especially found in the chronic cases. The finely granular cast seen in Fig. 90, *a*, may be found in such cases, or in the subacute form of the disease.

Fatty Casts, or **Oil Casts**, are such as reveal oil drops in the cast material. They occur in chronic nephritis attended by fatty degeneration. It is sometimes difficult to determine whether the granular degeneration seen in these casts is due to the degeneration of the cast itself, after having been formed, or whether it is the result of the disintegration of blood or epithelium cells. These casts form in the tubules and often remain there for a considerable time—a sufficient time, perhaps, to undergo granular and even fatty degeneration. It is certain that the coarsely granular and fatty casts are never found in the first stages of the disease.

Waxy Casts are a variety resembling hyaline casts in some instances, but are more dense and more distorted, and frequently are cracked or torn along the edges, or they have lost the regularity of their outline. They give a blue color with sulphuric acid and iodine.

Mucous Casts are frequently spoken of. They are long, transparent, fibrillar bodies, twisted and branching, and lacking in the terminal features of casts. They should not be regarded as casts, although we may meet with mucous plugs from the follicles in the prostatic urethra, which closely resemble casts. The character of the epithelium, with which they are associated, will usually serve to distinguish them. The absence of albumin will also assist.

Casts can usually be readily distinguished from other bodies met with in the urine by the peculiarly rounded end, formed by the pushing of the cast material through the tubule by pressure from behind, while still in a plastic condition. This rounded extremity is one of the most characteristic features in casts, and when in doubt as to the identity of an object, this will often serve as a guide.

FIG. 91.

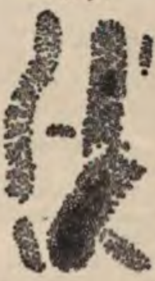
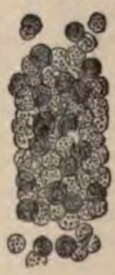


FIG. 92.



Casts formed of **urates** will occasionally be met with and always resemble granular casts. (See Fig. 91.) Masses of micrococci, closely resembling casts, will also occasionally be seen, but these can usually be distinguished by their appearance or by their resistance to reagents, as caustic, potash, nitric acid, etc. **Leucocyte Casts** (Fig. 92) are met with in suppurating conditions of the tubules of the kidney.

Granular Detritus.—Under this name we will designate the ill defined granular or disintegrating masses of material frequently met with in cases of nephritis. These irregular or amorphous masses are probably due to partially disintegrated cells or masses of free granules of this origin. The amount of this material in any specimen of nephritic urine, should be noted as an aid in arriving at a clear idea of the amount of destructive change going on in the kidney. This point is an important one in prognosis, as by it we are able to determine that organic destruction of the kidney is rapidly progressing and the prognosis unfavorable; or, that there is little or no organic destruction and the prognosis better.

The following scheme for the chemical and microscopical examination will be found useful as a guide to rapid work:—

URINARY DEPOSITS.

CHEMICAL EXAMINATION.

Draw off a portion of the sediment with a pipette or glass tube, and transfer to a watch glass or small test-tube.

- White Deposit.
  - Dissolves on heating urine, ... *Ammonium urate.*
  - Insoluble on heating
    - Sol. in NH_4OH, ... *Cystin.*
    - Insol. in NH_4OH,
      - Soluble in acetic acid, *Earthy Phosphates.*
      - Insoluble in acetic acid, *Calcium oxalate* or *oxalurate.*
    - Gelatinizes in NH_4OH, *Pus* (see above).
- Colored Deposit.
  - Visibly crystalline (red), ... *Uric acid.*
  - Amorphous,
    - Pale, easily soluble by heat, ... *Urates.*
    - Deep colored, slowly soluble by heat, *Acid urates with uroerythrin.*
    - Red, insoluble by heat, alkalies or acids, . *Blood.*

MICROSCOPICAL EXAMINATION.

With a clean pipette, draw off a small portion of the sediment, transfer to a clean glass slide, and examine with a ½ in. or ¼ in. objective. A cover glass may be dispensed with.

- Deposit is Amorphous.
  - Small granules with spicules on larger granules, ...
    - light *Sodium urate.*
    - dark *Ammonium urate.*
  - Vanishes on adding KOH or NaOH
  - Permanent, " " " *Calcium phosphate* (rare).
  - Globules, strongly refracting light . . . . *Fat.*

Deposit is Crystalline.	Urine, Acid.	Reddish, cross or whetstone shaped, or in groups,	*Uric acid.*
		Regular octahedra, envelope-shaped, .	*Calcium oxalate.*
		Hexagonal plates, soluble in NH_4OH (white), .	*Cystin.*
		Bundles of needles crossing each other, . . .	*Tyrosin.*
	Alkaline Urine.	Large prisms, soluble in acetic acid (coffin-lid shaped),	*Ammon. magnesium phosphate.*
		Brown, double spheres, spiculated,	*Urate of ammonium.*
		Club-shaped crystals, single or in groups,	*Calcium phosphate.*
		Double spheres, radiated structure, soluble in acetic acid, with effervescence,	*Calcium carbonate* (rare).
		Double spheres, insoluble in acetic acid,	*Calcium oxalurate* (rare).
		Double spheres, yellow, or red, radiated, .	*Uric acid.*
Cellular Elements.	Red or yellow discs, biconcave; sometimes irregular in outline,		*Blood cells.*
	Granulated corpuscles. With diluted acetic acid show 3 to 5 nuclei,	Albumen present	*Pus.*
		Albumen absent,	*Mucous corpuscles.*
	Round, conical, or flat cells with one nucleus,		*Epithelium from urinary tract.*
	Tadpole-shape, with long tail, ...		*Spermatozoa.*
	Cylinders, parallel margins, clear, granular, or containing epithelial cells or blood cells, ...		*Casts of uriniferous tubules.*
	Fungi, yeast, hairs, threads, etc., etc., . .		*Extraneous matters.*

URINARY CALCULI.

Urinary calculi, or concretions, are hard masses of urinary sediments formed in the kidney, ureters, bladder, or sinuses of the prostate gland. They are **simple,** or composed of one kind of material, or **compound** or **mixed,** composed of two or more kinds of material, deposited in concentric layers. In the examination of a calculus it should be sawed through so as to expose these layers, and small portions of each layer examined separately. An examination of a calculus is necessary to determine the condition which led to its formation, and to suggest proper treatment to prevent the formation of others. About 60 per cent. of all urinary calculi are composed of uric acid or acid urates. They are generally reddish and smooth, but sometimes tuberculated. About 40 per cent. of the remainder of the stones are mixed uric acid and earthy phosphates, containing rather more of the latter ingredients. When the calculus starts as an uric acid concretion, and the urine changes from acid to alkaline, the phosphates are deposited. This is apt to occur sooner or later. The cross section of such a calculus shows very plainly the different layers.

Calcium Oxalate, or **mulberry** calculi, comprises about three per cent. of all cases operated upon. They are gray or dark-brown, very hard, and generally tuberculated. When smooth they are often called "hemp-seed calculi."

The phosphatic calculi are rare, as are those composed of calcium carbonate, cystin, xanthin, fibrin, blood, indigo, and urostealite.

These last are very rare, but have been met with.

The following is a scheme for the qualitative examination of calculi:—

Heat a portion of the powdered stone on a platinum foil or charcoal with blowpipe.

A. *It chars and burns with a flame.* Probably xanthin, cystin, urostealite, or fibrin.

1. The flame burns briefly, and the powder dissolves in ammonia, and on diluting deposits six-sided plates = **Cystin.**

2 It does not give the murexid test. The powder is soluble in HNO_3 without effervescence, and the dried residue becomes orange with alkalies and red on warming = **Xanthin.**

3. The flame is yellow, prolonged, and gives the odor of burning shellac. The powder is soluble in alcohol = **Urostealite.**

4. The flame is yellow, prolonged, and gives the odor of burning feathers. Soluble in hot KOH solution, and is precipitated again by acetic acid = **Fibrin.**

B. *It chars, but does not burn with flame.*

1. The powder gives the murexid test.

a. It gives off NH_3 when warmed with KOH solution = **Urate of Ammonium.**

b. It gives no NH_3 with KOH = **Uric Acid.**

C. *The powder does not strongly char or burn.* Treated with diluted, HCl.

1. It dissolves with effervescence = **Calcium Carbonate.**

2. It dissolves without effervescence, and the solution gives a white precipitate with NH_4OH = **Phosphates** or **Calcium Oxalate.**

Treat the powder with acetic acid.

Phosphates dissolve without effervescence.

Mixed phosphates fuse in heating on foil.

Calcium phosphate does not fuse.

Triple phosphate gives off NH_3 when warmed with a little KOH solution.

Calcium Oxalate is insoluble in acetic acid. After ignition it gives an alkaline powder, which effervesces with acetic or diluted HCl.

THE URINE OF THE TWENTY-FOUR HOURS—NORMAL AND PATHOLOGICAL.

The subjoined table gives the most prominent variations in physical and chemical characters, with brief notes of their significance. As there are numerous handbooks upon this subject, the student is referred to them for details:—

PHYSICAL CHARACTER.	NORMAL.	ALTERATIONS IN ABNORMAL CONDITIONS.
Color.	Pale straw to reddish-yellow. The average color is Amber.	Colorless: neuroses, chronic nephritis, diabetes. High colored: acute fevers. Blood red: blood or foreign color. Dark brown: hæmaturia, poisoning by carbolic acid, potass. chlorate, or iodoform. Smoky brown: presence of decomposed blood in acute nephritis. Yellow or green: presence of bile. White: chyle or pus.
Transparency.	Clear, with only a slight flocculent cloud of mucus.	Urine turbid when passed, is abnormal. Whitish sediment may be pus, phosphates, or ammonium urate.
Consistence.	When normal, urine is mobile, like Water.	When viscid, it indicates albumin, bile, or pus.
Odor.	Peculiar to itself.	Urine putrid when passed, indicates cystitis.
Reaction.	Slightly acid; becomes more acid on standing, then becomes alkaline.	Urine strongly acid in fevers and inflammations of the liver, heart, and lungs; in acid dyspepsia. Urine is alkaline in cystitis, and occasionally in debility, chlorosis, certain organic nervous diseases, typhus, etc.

CONSTITUENTS	AMOUNT IN GRAINS.	ALTERATIONS IN PATHOLOGICAL CONDITIONS.
Sulphuric acid.	23 to 38	Having more or less the same source as urea, it will increase or diminish therewith. Occurs as sulphuric ethers.
Phosphoric acid.	46 to 54	Increased in fevers, in nerve exhaustion, disease of spinal cord, and in tubercle of the lung. In phosphatic diabetes the alkaline phosphates are greatly increased.

THE URINE OF THE TWENTY-FOUR HOURS—NORMAL AND PATHOLOGICAL.—*Continued.*

Constituents.	Amount in Grains.	Alterations in Pathological Conditions.
		Diminished in many mental diseases, especially mania, and in chlorosis.
Oxalic acid.	0.3	**Increased** in catarrhal jaundice, and in oxalic acid diathesis, mental depression, and certain forms of dyspepsia.
Carbolic acid.	0.015	**Increased** in certain diseases of the intestines, causing constipation (ileus, etc.), but has been observed to be increased also in certain cases of diarrhœa.
Phosphate of lime.	4 to 5	**Increased** in osteomalacia, rickets, scrofula, carcinoma, long-continued suppuration, organic disease of the spinal cord. **Diminished** in fevers.
Phosphate of magnesium.	7 to 11	
Chloride of sodium.	150 to 200 Cl = 90 to 120 Na = 60 to 80	**Increased** in fevers at the outset, and with the re-absorption of dropsical fluids. **Diminished** during apyrexia, dropsies, cholera, typhus, inflammations generally, and especially in the forming stage of pneumonia.
Free acid (calculated as oxalic acid).	30 to 60	**Increased** during the acme of acute febrile affections (on account, probably, of the diminished proportion of water present). **Diminished** in most diseases affecting the nutrition and leading to a deficiency thereof.
Indican.	0.07 to 0.05	**Increased** with diseases attended by constipation and intestinal fermentation, and occasionally, also, in cases of diarrhœa. After cholera, cancer of the liver and stomach, purulent peritonitis. Valuable diagnostic sign in typhoid fever and cancer of the liver.
Total inorganic salts	200 to 380	
Potassium.	38 to 48	
Sodium.	140 to 180	
Calcium.	4 to 5	
Magnesium.	2 to 3	
Mucus.	Variable.	**Increased** by any irritation of the urinary tract, due to uric acid, oxalate of calcium, earthy phosphates, etc. Also in catarrh of the bladder or urethra. Increased in acute fevers, and in females from leucorrhœal discharge.

APPENDIX.

RULES FOR THE SPELLING AND PRONUNCIATION OF CHEMICAL TERMS.

ADOPTED BY THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN 1891.

In 1887 a committee was appointed by the American Association for the Advancement of Science to consider the question of attaining uniformity in the spelling and pronunciation of chemical terms. The work of this committee extended through the following four years. As a result of widespread correspondence and detailed discussion at the annual meetings of the Chemical Section of the American Association, the accompanying rules have been formulated and adopted by the Association. They are submitted to chemists generally, and especially to the large number of those engaged in teaching chemistry, with the request that a cordial and earnest effort be made to render their use general, and thus obviate the many difficulties arising from the present diversities of style.

The following summary of the rules has been arranged in the form of a chart, by the National Bureau of Education, for general distribution to high schools and colleges.

For the reasons stated in the preface, we have not adopted the spelling here recommended for those substances that are official. We have, however, adopted it in the names of the newer synthetic remedies, and in organic compounds not used in medicine.

It is yet a matter of doubt whether these rules will be generally adopted by English-speaking chemists. English chemists are not generally favorably disposed towards the reforms proposed.

GENERAL PRINCIPLES OF PRONUNCIATION.

1. The pronunciation is as much in accord with the analogy of the English language as possible.

2. Derivatives retain as far as possible the accent and pronunciation of the root word.

3. Distinctly chemical compound words, retain the accent and pronunciation of each portion.

4. Similarly sounding endings for dissimilar compounds are avoided (hence **-id, -ite**).

ACCENT.

In polysyllabic chemical words the accent is generally on the antepenult; in words where the vowel of the penult is followed by two consonants, and in all words ending in **-ic**, the accent is on the penult.

PREFIXES.

All prefixes in strictly chemical words, are regarded as parts of compound words, and retain their own pronunciation unchanged, (as ă′ceto-, ă′mĭdo-: ă′zo-, hȳ′dro-, ĭ′so-, nĭ′tro-, nitrŏ′so-).

ELEMENTS.

In words ending in **-ium**, the vowel of the antepenult is short if **i** (as īrĭ′dium), or **y** (as dĭdy̆′mium), or if before two consonants (as că′lcium), but long otherwise (as tĭtā′nium, sĕlē′nium, chrō′mium).

alū′minum.
a′ntimony.
a′rsĕnic.
ba′rium.
bi′smuth (biz).
bō′ron.
brō′mĭn.
că′dmium.
că′lcium.
ca′rbon.
cē′rium.
cē′sium.
chlō′rin.
chrō′mium.
cō′balt.
colŭ′mbium.
co′pper.
dĭdy̆′mium.
e′rbium.
flū′orĭn.
gă′llium.
germa′nium.
glū′cinum.

gold.
hȳ′drogen.
Ĭ′ndium.
ī′odin.
īrĭ′dium.
iron.
lă′nthanum.
lead.
lĭ′thium.
magnē′sium (zhium).
ma′nganese (eze).
me′rcury.
mōly̆′bdenum.
nĭ′ckel.
nī′trogen.
ŏ′smium.
ŏ′xygen.
palla′dium.
phŏs′phorus.
plă′tinum.
potă′ssium.
rhō′dium.
rubĭ′dium.

ruthē′nium.
sama′rium.
scă′ndium.
sĕle′nium.
sĭ′licon.
silver.
sō′dium.
strŏ′ntium (shium).
sŭ′lfur.
tă′ntalum.
tellū′rium.
te′rbium.
thă′llium.
thō′rium.
tin.
tĭtă′nium.
tŭ′ngsten.
ūrā′nium.
văna′dium.
ytte′rbium.
y̆′ttrium.
zinc.
zircō′nium.

Also ămmō'nium, phosphō'nium, hă'logen, cȳă'nogen, ămĭ'dogen.

Note in the above list the spelling of the halogens, cesium, and sulfur; **f** is used in the place of **ph** in all derivatives of sulfur (as sulfuric, sulfite, sulfo-, etc.).

TERMINATIONS IN **-ic.**

The vowel of the penult in polysyllables is short (as cȳă'nic, fūmă'ric, arsĕ'nic, silĭ'cic, īŏ'dic, būtў̆'ric), except (1) **u** when not used before two consonants (as mercū'ric, prŭ'ssic), and (2) when the penult ends in a vowel as benzō'ic, olē'ic); in dyssyllables it is long except before two consonants (as bō'ric, cĭ'tric). Exception: acē'tic or acĕ'tic.

The termination **-ic** is used for metals only where necessary to contrast with **-ous** (thus avoid aluminic, ammonic, etc.).

TERMINATIONS IN **-ous.**

The accent follows the general rule (as plă'tinous, sŭ'lfurous, phŏ'sphorous, coba'ltus). Exception: acē'tous.

TERMINATIONS IN **-ate** AND **-ite.**

The accent follows the general rule (as ă'cetāte, vă'nadāte); in the following words the accent is thrown back: ă'bietāte, ă'lcoholāte, ă'cetonāte, ă'ntimonīte.

TERMINATIONS IN **-id** (FORMERLY **-ide**).

The final **e** is dropped in every case and the syllable pronounced **id** (as chlō'rĭd, ĭ'odĭd, hȳ'drĭd, ŏ'xĭd, hȳdrŏ'xĭd, sŭ'lfid, ă'mĭd, ă'nilĭd, mūrĕ'xĭd).

TERMINATIONS IN **-ane, -ene, -ine,** AND **-one.**

The vowel of these syllables is invariably long (as mĕ'thāne, ĕ'thāne, na'phthalēne, a'nthracēne, prō'pīne, quĭ'nōne, ă'cetōne, kē'tōne).

A few dissyllables have no distinct accent (as benzēne, xȳlēne, cētēne).

The termination **-ine** is used only in the case of doubly unsaturated hydrocarbons, according to Hofmann's groupings (as propīne).

TERMINATIONS IN -in.

In names of chemical elements and compounds of this class, which include all those formerly ending in **-ine** (except doubly unsaturated hydrocarbons), the final **e** is dropped, and the syllable pronounced **ĭn** (as chlō'rĭn, brō'mĭn, etc., ă'mĭn, ă'nilĭn, mo'rphĭn, quĭ'nĭn (kwĭ'nĭn), vanĭ'llĭn, alloxă'nthĭn, absi'nthĭn, emŭ'lsĭn, că'ffeĭn, cō'caĭn.

TERMINATIONS IN -ol.

This termination, in the case of specific chemical compounds, is used *exclusively* for alcohols, and when so used is never followed by a final **e**. The last syllable is pronounced **-ōl** (as glȳ'cōl, phē'nōl, crē'sōl, thȳ'mōl (ti), gly̆'cerol, quĭ'nōl. Exceptions: ălcohŏl, a'rgŏl.

TERMINATIONS IN -ole.

This termination is always pronounced **-ōle**, and its use is limited to compounds which are not alcohols (as ĭ'ndōle).

TERMINATIONS IN -yl.

No final **e** is used; the syllable is pronounced **y̆l** (as ă'cety̆l, ă'my̆l, cē'roty̆l, cē'ty̆l, ĕ'thy̆l).

TERMINATIONS IN -yde.

The **y** is long (as ă'ldehȳde).

TERMINATIONS IN -meter.

The accent follows the general rule (as hydrŏ'meter, barŏ'meter, lactŏ'-meter). Exceptions: Words of this class used in the metric system are regarded as compound words, and each portion retains its own accent (as cĕ'ntime"ter, mi'llime"ter, kĭ'lome"ter.

MISCELLANEOUS WORDS

which do not fall under the preceding rules.

Note the spelling: Albumen, albuminous, albuminiferous, asbestos, gramme, radical.

Note the pronunciation: A'lkalīne, a'lloy (n. and v.), a'llotropy, a'llotropism, ī'somerism, pŏ'lymerism, apparā'tus (sing. and plu.), ā'qua regia, bary̆'ta, cĕntigrade, co'ncentrated, crystallĭn or crystallīne, electrŏ'lysis, līter, mŏ'lecule, mŏlĕ'cular, nō'menclā"ture, olē'fiant, vā'lence, ū'nivā"lent, bī'va"lent, trī'vā"lent, qua'drivā"lent, tĭ'trate.

A LIST OF WORDS WHOSE USE SHOULD BE AVOIDED IN FAVOR OF THE ACCOMPANYING SYNONYMS.

For—	Use—
sodic, calcic, zincic, nickelic, etc.,	sodium, calcium, zinc, nickel, etc.
chlorid, etc.,	chlorid, etc. (*vid.* termination in -ic, *supra.*
arsenetted hydrogen,	arsin.
antimonetted hydrogen,	stibin.
phosphoretted hydrogen,	phosphin.
sulfuretted hydrogen,	hydrogen sulfid, etc.
beryllium,	glucinum.
niobium,	columbium.
glycerin,	glycerol.
hydroquinone (and hydrochinon),	quinol.
pyrocatechin,	catechol.
resorcin, etc.,	resorcinol, etc.
mannite,	mannitol.
dulcite, etc.,	dulcitol, etc.
benzol,	benzene.
toluol, etc.,	toluene, etc.
thein,	caffein.
furfurol,	furfuraldehyde.
fucusol,	fucusaldehyde.
anisol,	methyl phenate.
phenetol,	ethyl phenate.
anethol,	methyl allyl-phenol.
alkylogens,	alkyl-haloids.
titer (n.),	strength or standard.
titer (v.),	titrate.
monovalent,	univalent.
divalent,	bivalent, etc.
quantivalence,	valence.

Fāte, făt, fär, mēte, mĕt, pīne, pĭn, marïne, nōte, nŏt, mōve, tūbe, tŭb, rüle. mȳ = ī.

′ Primary accent; ″ secondary accent. N. B.—The accent follows the vowel of the syllable upon which the stress falls, but does not indicate the division of the word into syllables.

TABLE OF WEIGHTS AND MEASURES.

ENGLISH WEIGHTS.

TROY WEIGHT.

Pound.	*Ounces.*	*Pennyweights.*	*Grains.*		*Grammes.*
1	12	240	5760	=	373.2419
	1	20	480	=	31.1035
		1	24	=	1.5552

APOTHECARIES' WEIGHT.

℔ *Pound.*	℥ *Ounces.*	ʒ *Drachms.*	℈ *Scruples.*	gr. *Grains.*		*Grammes.*
1	12	96	288	5760	=	373.2419
	1	8	24	480	=	31.1035
		1	3	60	=	3 8879
			1	20	=	1.2959
				1	=	.0648

AVOIRDUPOIS WEIGHT.

Pound.	*Ounces.*	*Drachms.*	*Grains.*		*Grammes.*
1	16	256	7000	=	453.5926
	1	16	437.5	=	28.3495
		1	27.343	=	1.7718

METRIC MEASURES.

MEASURES OF LENGTH.

1	Millimeter	=	0.001 of a meter.		
1	Centimeter	=	0.010 of a meter.		
1	Decimeter	=	0.100 of a meter	=	about 4 inches.
1	**Meter**	=	**1.000 Meter**	=	**39.37 inches.**
1	Decameter	=	10.000 meters.		
1	Hectometer	=	100 000 meters.		
1	Kilometer	=	1000.000 metres	=	about ⅝ of a mile.
1	Myriameter	=	10,000.000 meters	=	about 6⅕ miles.

MEASURES OF SURFACE.

1	Centaire	=	1 Square meter	=	about 1⅕ square yards.
1	**Are**	=	**100 Square meters.**		
1	Hectare	=	10,000 Square meters	=	about 2½ acres.

MEASURES OF VOLUME.

1	Cubic centimeter	=	0.001 of a liter.
1	Liter (cubic decimeter)	=	1000. cubic centimeters.
1	Cubic meter	=	1000 cubic decimeters.
1	Cubic meter	=	1000. liters, or 1 kiloliter.
1	Cubic meter	=	1 stere.

MEASURES OF WEIGHT.

1	Milligramme	=	0.001 of a gramme	=	about 1/65 of a grain.
1	Centigramme	=	0 010 of a gramme.		
1	Decigramme	=	0.100 of a gramme.		
1	**Gramme***	=	**1 000 Gramme**	=	**about 15½ grains.**
1	Decagramme	=	10.000 grammes.		
1	Hectogramme	=	100 000 grammes.		
1	Kilo(gramme)	=	1000.000 grammes	=	about 2⅕ pounds.
1	Tonneau	=	1000. Kilos	=	about 1 ton.

* Sometimes spelled *gram* in English and American books.

TABLES FOR THE CONVERSION OF WEIGHTS AND MEASURES.

Based upon the value 39 37 in. for the meter and 15432 2 grains for the kilogramme.

The following tables embrace the chief measures of length, weight, and capacity, giving the required equivalents of the nine units. Higher numbers are found by moving the decimal point to the right, and fractions by moving it to the left. Thus, if it be desired to find the equivalent of 125 grains in milligrammes, we proceed as follows: By the table

1 gr. = 64.80 mgrms., and 100 grs. then = 6480. mgrms.
2 grs. = 129.6 " " 20 " " = 1296. "
5 grs. = 324. " " 5 " " = 324. "
125 grs 8100. milligrammes.

As 1000 mgrms. = 1 grm., the above would be 8.100 grms.

If it be desired to find the value of 1.45 grms. in grains we proceed as follows:—

1 grm. = = 15.43 grains.
4 grms. = 61.72 grains .4 gms. = 6.172 "
5 grms. = 77.15 " .05 " = .7715 "
22.3735 grains.

Grains.	Mgrms.	Inches.	Milli-meters.	Fl. Oz.		C.C.	Minims.
1 =	64.8	1 =	25.4	1 =	29.7	1 =	16.2
2 =	129.6	2 =	50.8	2 =	60.0	2 =	32.4
3 =	194.4	3 =	76.2	3 =	90.	3 =	48.6
4 =	259.2	4 =	101.6	4 =	120.	4 =	64.8
5 =	324.0	5 =	127.0	5 =	150.	5 =	81.0
6 =	388.8	6 =	152.4	6 =	180.	6 =	97.2
7 =	453.6	7 =	177.8	7 =	210.	7 =	113.4
8 =	518.4	8 =	193.2	8 =	240.	8 =	129.6
9 =	583.2	9 =	228.6	9 =	270.	9 =	145.8

Troy. Oz.	Grms.	Feet.	Meters.	Pints.	Liters.	C.C.	Fl. Drachms.
1 =	31.1	1 =	0.3048	1 =	0.473	1 =	0.27
2 =	62.2	2 =	0.6096	2 =	0.946	2 =	0.54
3 =	93.3	3 =	0.9144	3 =	1.419	3 =	0.81
4 =	124.4	4 =	1.2192	4 =	1.892	4 =	1.08
5 =	155.5	5 =	1.5240	5 =	2.365	5 =	1.35
6 =	186.0	6 =	1.8288	6 =	2.838	6 =	1.62
7 =	217.7	7 =	2.1336	7 =	2.311	7 =	1.89
8 =	248.8	8 =	2.4384	8 =	3.784	8 =	2.16
9 =	279.9	9 =	2.7432	9 =	4.257	9 =	2.43

Av. Oz.		Minims.	C.C	Grms	Grains.	Liters.	Fl. Oz.
1 =	28.35	1 =	.0616	1 =	15.43	1 =	33.8
2 =	56.70	2 =	.1232	2 =	30.86	2 =	67.6
3 =	85.05	3 =	.1848	3 =	46.29	3 =	101.4
4 =	113.40	4 =	.2464	4 =	61.72	4 =	135.2
5 =	141.75	5 =	.3080	5 =	77.15	5 =	169.0
6 =	170.10	6 =	.3696	6 =	92.58	6 =	202.8
7 =	198.45	7 =	.4312	7 =	108.01	7 =	236.6
8 =	226.80	8 =	.4928	8 =	123.44	8 =	270.4
9 =	255.15	9 =	.5544	9 =	138.87	9 =	304.2

Av. Pounds.	Kilo-Grms.	Fl Drachms.	C.C.	Kilos.	Av. Oz.	Liters.	Cu. Inches.
1 =	0.4536	1 =	3.7	1 =	2.2	1 =	61.
2 =	0.9072	2 =	7.4	2 =	4.4	2 =	122.
3 =	1.3608	3 =	11.1	3 =	6.6	3 =	183.
4 =	1.8144	4 =	14.8	4 =	8.8	4 =	244.
5 =	2.2680	5 =	18.5	5 =	11.0	5 =	305.
6 =	2.7216	6 =	22.2	6 =	13.2	6 =	366.
7 =	3.1752	7 =	25.9	7 =	15.4	7 =	427.
8 =	3.6228	8 =	29.6	8 =	17.6	8 =	488.
9 =	4.0824	9 =	33.3	9 =	19.8	9 =	549.

ALPHABETICAL TABLE OF EQUIVALENT MEASURES.

1 Are . . . . = 100 sq. meters = 119.6 sq. yards.
1 Barrel (wine) . . . . = 1.192 hectoliters.
1 Barrel (imperial) . . . . = 1.635 hectoliters.
1 Bushel (dry) . . . . = 35.243 liters.
1 Centimeter . . . . = $\frac{1}{100}$ mer = .3937 inch.
1 Cubic centimeter . . . . = 16.2 minims = .06102 cu. in.
1 Cubic centimeter of dist. water at 4° C. . . . . weighs 1 gram.
1 Cubic decimeter (1 liter) (1000 c.c.) of dist. water . . . weighs 1 kilogram.
1 Cubic decimeter (imperial measure) . . . . = 61.03 cu. in. = 0.8804 qt.
1 Cubic decimeter (American wine measure) = 33.8 fluid ounces or 1.056 qts.
1 Cubic foot . . . . = 1628 cu. in. = 28,315.31 c.c.
1 Cubic foot of water at 62° F. (16.6° C.) . . . . weighs 62.32 lbs. av.
1 Cubic inch . . . . = 266 minims = 16.386 c.c.
1 Cubic inch of water at 62° F. (16.6 ° C.) weighs 252.46 grs. = 16.372 grams.
1 Cubic meter (1 stere) . . . . = 1000 liters = 35.30 cu. ft.
1 Drachm (Troy) . . . . = 3.888 grams = 60 grains.
1 Fluid drachm . . . . = 60 minims = 3.697 c.c.
1 Fluid ounce (imperial) . . . . = 28.4 c.c. = 1.7329 cu. in.
1 Fluid ounce (wine measure) . . . . = 29.57 c.c. = 1.8047 cu. in.
1 Fluid ounce of water (wine measure) at 62° F. . . . . weighs 456 grains.
1 Fluid ounce of water (wine measure) at 60° F. . . . . weighs 29.57 grams.
1 Fluid ounce of water (imperial) at 62° F. . . . . . . weighs 437.5 grains.
1 Foot (12 inches) . . . . = 34.48 centimeters.
1 Gallon (imperial) . . . . = 277.27 cu. in. = 4.543 liters.
1 Gallon (wine) . . . . = 231 cu. in. = 3.785 liters.
1 Gallon of water (imperial) . . . . . weighs 10 lbs. Wine gallon, 8.34 lbs.
1 Grain Troy . . . . = 0.0648 gram.
1 Gram. (weight of 1 c.c. of water at 4° C., 39.2° F.) . . = 15.4233 grains.
1 Inch . . . . = 2.54 centimeters.
1 Kilogram . . . . = 1000 grams. = 2.7 lbs. Troy = 2.2046 lbs. av.
1 Liter (see cubic decimeter) . . . . = 61.027 cu. in.
1 Meter (one forty-millionth of earth's meridian) . . . . . . = 39.3708 in.
1 Minim . . . . = 0.0616 c.c. 1 minim of water weighs 0.95 grain.
1 Ounce (Troy) . . . . = 480 grains = 31.1 grams.
1 Ounce (avoirdupois) . . . . = 437.5 grains = 28.35 grams.
1 Pint (imperial) . . . . = 20 fluid ounces = 567.93 c.c.
1 Pint (wine measure) . . . . = 16 fluid ounces = 473.15 c.c.
1 Pound (Troy) . . . . = 5760 grains = 373.24 grams.
1 Pound (avoirdupois) . . . . = 7000 grains = 453.59 grams.
1 Quart (imperial), 40 fluid ozs. . . . . . . = 69.97 cu. in. = 1.1358 liters.
1 Quart (wine measure), 32 fluid ozs. . . . . = 58.30 cu. in. = 0.9463 liter.
1 Ton (avoirdupois) . = 2000 lbs. = 29,167 ozs. Troy = 907.20 kilograms.
1 Tonneau . . . . = 1,000,000 grams = 1000 kilos = 2204.6 lbs. av.

TABLE OF SPECIFIC GRAVITIES NAMED IN THE U. S. PHARMACOPŒIA, 1890.

Compiled by Dr. J. F. Golding.

	AT 15° C.
Acidum aceticum,	about 1.048
“ “ dilutum,	about 1.008
“ “ glaciale,	not higher than 1.058
“ hydrobromicum dilutum,	about 1.077
“ hydrochloricum,	about 1.163
“ “ dilutum,	about 1.050
“ hypophosphorosum dilutum,	about 1.046
“ lacticum,	about 1.213
“ nitricum,	about 1.414
“ “ dilutum,	about 1.057
“ oleicum,	about 0.900
“ phosphoricum,	not below 1.710
“ “ dilutum,	about 1.057
“ sulphuricum,	not below 1.835
“ “ aromaticum,	about 0.939
“ “ dilutum,	about 1.070
“ sulphurosum,	not less than 1.035
Adeps,	about 0.932
Æther, Ether,*	0.725 to 0.728
“ “ aceticus,	0.893 to 0.895
Alcohol,†	about 0.820
“ absolutum,‡	not higher than 0.797
“ deodoratum,§	about 0.816
“ dilutum,‖	about 0.937
Amyl Nitris,	0.870 to 0.880
Aqua ammoniæ,	0.960
“ “ fortior,	0.901
“ hydrogenii dioxidi,	about 1.006 to 1.012
Balsamum peruvianum,	1.135 to 1.150
Benzinum,	0.670 to 0.675
Bromum,	2.990
Camphora,	0.995
Carbonei disulphidum,	1.268 to 1.269
Cera alba,	0.965 to 0.975
“ flava,	0.955 to 0.967
Cetaceum,	about 0.945
Chloroform,¶	not below 1.490
Copaiba,	0.940 to 0.990
Creasotum,	not below 1.070
Eucalyptol,	0.930
Fel bovis,	1.018 to 1.028
Glycerinum,	not less than 1.250
Hydrargyrum,	13.5584
Iodoformum,	2.000
Iodum,	**
Limonis succus,	not less than 1.030
Liquor ferri acetatis,	about 1.160
“ “ chloridi,	about 1.387
“ “ citratis,	about 1.250
“ “ nitratis,	about 1.050

	AT 15° C.
Liquor ferri subsulphatis,	about 1.550
“ “ tersulphatis,	about 1.320
“ hydrargyri nitratis,	about 2.100
“ plumbi subacetatis,	about 1.195
“ potassæ,	about 1.036
“ sodæ,	about 1.059
“ “ chloratæ,	about 1.052
“ sodii silicatis,	1.300 to 1.400
“ zinci chloridi,	about 1.535
Mel,	1.375
Methyl salicylas,	1.183 to 1.185
Oleum adipis,	0.910 to 0.920
“ Æthereum,	0.910
“ amygdalæ amaræ,	1.060 to 1.070
“ “ expressum,	0.915 to 0.920
“ anisi,	††
“ aurantii corticis,	about 0.850
“ “ florum,	0.875 to 0.890
“ bergamottæ,	0.880 to 0.885
“ cadinum,	about 0.990
“ cajuputi,	0.922 to 0.929
“ cari,	0.910 to 0.920
“ caryophylli,	1.060 to 1.067
“ chenopodii,	about 0.970
“ cinnamomi	1.055 to 1.065
“ copaibæ,	0.890 to 0.910
“ coriandri,	0.870 to 0.885
“ cubebæ,	about 0.920
“ erigerontis,	about 0.850
“ eucalypti,	0.915 to 0.925
“ fœniculi,	not less than 0.960
“ gaultheriæ,	1.175 to 1.185
“ gossypii seminis,	9.920 to 0.930
“ hedeomæ,	0.930 to 0.940
“ juniperi,	0.850 to 0.890
“ lavandulæ florum,	0.885 to 0.897
“ limonis,	0.858 to 0.859
“ lini,	0.930 to 0.940
“ menthæ piperitæ,	0.900 to 0.920
“ “ viridis,	0.930 to 0.940
“ morrhuæ,	0.920 to 0.925
“ myrciæ,	0.975 to 0.990
“ myristicæ	0.870 to 0.900
“ olivæ,	0.915 to 0.918
“ picis liquidæ,	about 0.970
“ pimentæ,	1.045 to 1.055
“ ricini,	0.950 to 0.970
“ rosæ,	‡‡
“ rosmarini,	0.895 to 0.915
“ sabinæ,	0.910 to 0.940
“ santali,	0.970 to 0.978
“ sassafras,	1.070 to 1.090
“ sesami,	0.919 to 0.923

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* 0.714 to 0.717 at 25° C.

† 0.812 at 25° C.

‡ 0.789 at 25° C.

§ 0.808 at 25° C.

‖ About 0.937 at 15° C.; about 0.936 at 15.6° C., and about 0.930 at 25° C.

¶ 1.473 at 25° C.

** 4.948 at 17° C.

†† About 0.980 to 0.990 at 17° C.

‡‡ 0.865 to 0.880 at 20° C.

TABLE OF SPECIFIC GRAVITIES. (*Continued.*)

	AT 15° C.
Oleum sinapis volatile,	1.018 to 1.029
" terebinthinæ,	0.855 to 0.870
" " rectificatum,	0.855 to 0.865
" theobromatis,	0.970 to 0.980
" thymi,	0.900 to 0.930
" tiglii,	0.940 to 0.960
Petrolatum liquidum,	about 0.875 to 0.945
" molle,	*
" spissum,	†
Phosphorus,	‡
Resina,	1.070 to 1.080
Spiritus ætheris nitrosi,	about 0.82
" ammoniæ,	about 0.810
" " aromaticus,	about 0.905
Spiritus frumenti,	not more than 0.930 nor less than 0.917
" glonoini,	0.826 to 0.832
" vini gallici,	not more than 0.941 nor less than 0.925
Syrupus,	about 1.317
" acidi hydriodici,	about 1.313
" ferri iodidi,	about 1.353
Terebenum,	about 0.862
Thymol,	solid—1.069 liquefied—lighter than water
Tinctura ferri chloridi,	about 0.960
Vinum album,	§
" rubrum,	‖
Zincum,	6.9 (cast) to 7.2 (rolled)

TABLE SHOWING THE SOLUBILITY OF SOME CHEMICALS IN GLYCERIN. ONE HUNDRED PARTS OF GLYCERIN DISSOLVE THE ANNEXED QUANTITIES OF THE SALTS.—(KLEVER.)

	PARTS.
Arsenious Oxide,	20.00
Arsenic Oxide,	20.00
Acid, Benzoic,	10.00
" Oxalic,	15.00
" Tannic,	50.00
Alum,	40.00
Ammonium Carbonate,	20.00
" Chloride,	20.00
Antimony and Potassium Tartrate,	5.50
Atropine,	3.00
" Sulphate,	33.00
Barium Chloride,	10.00
Brucine,	2.25
Cinchonine,	0.50
" Sulphate,	6.70
Copper Acetate,	10.00
" Sulphate,	30.00
Iron and Potassium Tartrate,	8.00
" Lactate,	16.00
" Sulphate,	25.00
Mercuric Chloride,	7.50
Mercurous Chloride,	27.00
Iodine,	1.90
Morphine,	0.45
Morphine Acetate,	20.00
" Hydrochlorate,	20.00
Phosphorus,	0.20
Plumbic Acetate,	20.00
Potassium Arsenate,	50.00
" Chlorate,	3.50
" Bromide,	25.00
" Cyanide,	32.00
" Iodide,	40.00
Quinine,	0.50
" Tannate,	0.25
Sodium Arsenate,	50.00
" Bicarbonate,	8.00
" Borate,	60.00
" Carbonate,	98.00
" Chlorate,	20.00
Sulphur,	0.10
Strychnine,	0.25
" Nitrate,	4.00
" Sulphate,	22.50
Urea,	50.00
Veratrine,	1.00
Zinc Chloride,	50.00
" Iodide,	40.00
" Sulphate.	35.00

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* About 0.820 to 0.840 at 60° C.

† About 0.820 to 0.850 at 60° C.

‡ 1.830 at 10° C.

§ Not less than 0.990, nor more than 1.010 at 15.6° C.

‖ Not less than 0.989 nor more than 1.010 at 15.6° C.

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL.

Explanation of Signs.

s. = soluble; *ins.* = insoluble; *sp.* = sparingly soluble; *v. s.* = very soluble; *alm.* = almost; *dec.* = decomposed.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j	At 59° F., or 15° C.	At 59° F., or 15° C., grs. pr. f℥j.
One part is soluble in :—	Parts.		Parts.	
Acetanilid,	200	2.28	10	37.4
Acid Arsenous,	30–80	15.2–57	sp.	. . .
" Benzoic,	500	0.9	3	124.6
" Boracic,	25	18.2	15	24.9
" Carbolic,	20	22.8	v. s.	. .
" Chromic,	v. s.	. . .	dec.	. . .
" Citric,	0.75	608	1	374
" Gallic,	100	4.5	4.5	83.1
" Salicylic,	450	1.01	2.5	149.6
" Tannic,	6	76	0.6	623
" Tartaric,	0.7	651	2.5	149.6
Agathin,	ins.	. . .	s.	. . .
Alphol,	ins.	. .	s.	. . .
Alum,	10.5	43.4	ins.	. . .
" Dry (Exsiccatum),	20	22.8	ins.	. . .
Aluminium Hydroxide,	ins.	. . .	ins.	. . .
" Sulphate,	1.2	380	alm. ins.	. . .
Alumnol,	s.	. . .	sp.	. . .
Ammonium Benzoate,	5	91.2	28	13.3
" Bromide,	1.5	304	150	2.4
" Carbonate,	4	114	dec.	. . .
" Chloride,	3	152	1.37	273
" Iodide,	1	456	9	41.5
" Nitrate,	0.5	912	20	18.7
" Phosphate,	4	114	0.5	748
" Sulphate,	1.3	350.7	sp.	. . .
" Valerianate,	v. s.	. . .	v. s.	. . .
Amylene Hydrate,	ins.	. . .	5	75
Analgene,	ins.	. . .	sp.	. . .
Anthrarobin,	ins.	. . .	5	91.2
Antimony and Potass. Tartrate,	17	26.8	ins.	. . .
" Oxide,	alm. ins.	. . .	ins.	. . .
" Sulphide,	ins.	. .	ins.	. . .
Antipyrin,	1	456	1	374
" Benzoate,	s. s.	. . .	sol.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

Name of Chemical.	Water.		Alcohol.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.
Antispasmin,	s.	. . .	ins.	. . .
Apomorphine Hydrochlorate,	6.8	67	50	7.4
Apyonin,	s. s.	. . .	sol.	. . .
Aristol,	ins.	. . .	s. s.	. . .
Arsenic Iodide,	3.5	130.2	10	37.4
Asaprol,	1½	304	3	152
Atropine,	600	0.7	v. s.	. . .
" Sulphate,	0.4	1140	6.5	57.5
Benzanilid,	ins.	. . .	60	6.2
Benzonaphthol,	ins.	. . .	sol.	. . .
Benzophenoneid,	100	4.6	. . .	. . .
Benzosol,	ins.	. . .	sol.	. . .
Petol,	ins.	. . .	diffic. sol.	. . .
Bismuth Citrate,	ins.	. . .	ins.	. . .
" and Ammon. Citrate,	v. s.	. . .	sp.	. . .
" Subcarbonate,	ins.	. . .	ins.	. . .
" Subnitrate,	ins.	. . .	ins.	. . .
Bromacetanilid,	ins.	. . .	diffic. sol.	. . .
Bromamid,	ins.	. . .	s. s.	. . .
Bromine,	33	13.8	dec.	. . .
Bromoform,	300	1.5	freely sol.	. . .
Bromol,	prac. ins.	. . .	freely sol.	. . .
Caffeine,	75	6.08	35	10.6
Caffeine-chloral,	s.	. . .	. . .	. . .
Caffeine-triiodide,	ins.	. . .	s.	. . .
Calcium Bromide,	0.7	651.4	1	374
" Carbonate,	ins.	. . .	ins.	. . .
" Chloride,	1.5	304	8	46.7
" Hypophosphite,	6.8	67	ins.	. . .
" Phosphate (precipitated),	ins.	. . .	ins.	. . .
Camphor, Monobromated,	alm. ins.	. . .	v. s.	. . .
Cerium Oxalate,	ins.	. . .	ins.	. . .
Chinolin,	ins.	. . .	5	74.8
" Salicylate,	80	5.7	sol.	. . .
" Tartrate,	80	5.7	150	3.8
Chloral,	v. s.	. . .	v. s.	. . .
Chloralamid,	10	45.6	2–3	187
Chloralammonium,	. . .	. . .	. . .	(124.6)
Chloralose,	170	2.68	s.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C., grs. pr. f℥j.
Chloral Urethan, ...	ins.	. . .	s.	. . .
Cinchonidine Sulphate, ...	100	4.5	71	5.2
Cinchonine, ...	alm. ins.	. . .	110	3.4
" Sulphate, ...	70	6.5	6	62.3
Codeine, ...	80	5.7	v. s.	. . .
Chalk (Creta), ...	ins.	. . .	ins.	. . .
Copper Acetate, ...	15	30.4	135	2.7
" Sulphate, ...	2.6	175.3	ins.	. . .
Creolin, ...	. . .	. . .	s.	. . .
Creosote, ...	ins.	. . .	v. s.	. . .
" carbonate, ...	ins.	. . .	s.	. . .
Cresalols, ...	ins.	. . .	s.	. . .
Cresol, Ortho, ...	37	12.3	s.	. . .
" Meta, ...	200	2.28	s.	. . .
" Para, ...	50	9.1	s.	. . .
Cresol Iodide, ...	ins.	. . .	s.	. . .
Cresotic Acids, ...	s. s.	. . .	s.	. . .
Dermatol, ...	ins.	. . .	ins.	. . .
Diaphterin, ...	s.	. . .	s.	. . .
Diaphtol, ...	sp.	. . .	s.	. . .
Di iodoform, ...	ins.	. . .	sp.	. . .
Di-iodo β Naphthol, ...	ins.	. . .	s. s.	. . .
Dithiosalicylic Acid I, ...	ins.	. . .	ins.	. . .
" " II, ...	ins.	. . .	v. s.	. . .
Diuretin, ...	v. s.	. . .	. . .	. . .
Dulcin, ...	800	.57	25	18.24
Elaterium, ...	ins.	. . .	125	2.9
Ethroxycaffeine, ...	sp.	. . .	s.	. . .
Ethyl Bromide, ...	ins.	. . .	s.	. . .
Ethylene Bromide, ...	ins.	. . .	s.	. . .
Euphorin, ...	ins.	. . .	s.	. . .
Europhen, ...	ins.	. . .	s.	. . .
Exalgin, ...	s. s.	. . .	s.	. . .
Ferric Chloride, ...	v. s.	. .	v. s.	. . .
" Citrate, ...	s.	. . .	ins.	. . .
" and Ammon. Citrate, ...	v. s.	. . .	ins.	. . .
" " " Sulphate, ...	3	152	ins.	. . .
" " " Tartrate, ...	v. s.	. . .	ins.	. . .
" " Potass. Tartrate, ...	v. s.	. . .	ins.	. . .
" " Quinine Citrate, ...	s.	. . .	ins.	. . .
" " Strychnine Citrate, ...	v. s.	. . .	ins.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C., grs. pr. f℥j.
Ferric Hypophosphite,	sp.	. . .	ins.	. . .
" Lactate,	40	11.4	alm. ins.	. . .
" Oxalate,	sp.	. . .	ins.	. . .
" Hydrate,	ins.	. . .	ins.	. . .
" Phosphate,	v. s.	. . .	ins.	. . .
" Pyrophosphate,	v. s.	. . .	ins.	. . .
" Sulphate,	1.8	253.3	ins.	. . .
" Valerianate,	ins.	. . .	v. s.	. . .
Fluorescein,	s.	. . .	. . .	. . .
Formanilid,	s.	. . .	s.	. . .
Formicaldehyde,	v. s.	. . .	v. s.	. . .
Gallacetophenone,	500	0.9	s.	. . .
Gallanol,	alm. ins.	. . .	s.	. . .
Gallobromol,	12	38	s.	. . .
Guaiacol,	85	5.3	s.	. . .
" carbonate,	ins.	. . .	sp.	. . .
" crystalline,	50	9.1	s.	. . .
" salicylate,	ins.	. . .	sp.	. . .
Hydracetin,	50	9.1	s.	. . .
Hydronaphthol,	s. s.	. . .	s.	. . .
Hydroquinone,	s. s.	. . .	s.	. . .
Hydroxylamine Hydrochlorate,	1	456	15	23.6
Hyoscyamine Sulphate,	v. s.	. . .	v. s.	. . .
Hypnal,	5–6	91.2–76	. . .	. . .
Hypnone,	ins.	(76)	s.	. . .
Ichthyol,	v. s.	. . .	s. s.	. . .
Iodoantipyrin,	s. s.	. . .	s. s.	. . .
Iodine,	sp.	. . .	11	34
Iodoform,	ins.	. . .	80	4.65
Iodol,	ins.	. . .	3	124.6
Iodophenin,	. . .	. . .	s.	. . .
Kairin,	6	76	20	13.7
Lactophenin,	s.		s.	. . .
Lanolin,	ins.	. . .	80 at (78° C.)	4.7
Lime (Calx),	750	0.6	ins.	. . .
Lithium Benzoate,	4	114	12	31.1
" Bromide	v. s.	. . .	v. s.	. . .
" Carbonate,	130	3.5	ins.	. . .
" Citrate,	5.5	82.9	sp.	. . .
" Salicylate,	v. s.	. . .	v. s.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.
Loretin,	500	0.9	s.	. . .
Losophan,	sp.	. . .	s.	. . .
Lycetol,	s.	. . .	. . .	. . .
Lysol,	v. s.	. . .	v. s.	. . .
Magnesium Oxide,	alm. ins.	. . .	ins.	. . .
" Carbonate,	alm. ins.	. . .	ins.	. . .
" Sulphate,	0.8	570	ins.	. . .
" Sulphite,	20	22.8	ins.	. . .
Malakin,	alm. ins.	. . .	diffic. sol.	. . .
Manganesium Dioxide (Black Oxide),	ins.	. . .	ins.	. . .
" Sulphate,	0.7	651.4	ins.	. . .
Mercuric Chloride,	16	28.5	3	124
Mercurous Chloride,	ins.	. . .	ins.	. . .
Mercuric Cyanide,	12.8	35.6	15	24.9
" Iodide (Red),	alm. ins.	. . .	130	2.8
Mercurous Iodide (Green),	alm. ins.	. . .	ins.	. . .
Mercuric Oxide,	ins.	. . .	ins.	. . .
" Subsulphate,	ins.	. . .	ins.	. . .
" Sulphide (Red),	ins.	. . .	ins.	. . .
Mercury Sozoiodol,	500	0.9	. . .	. . .
Metaldehyde,	ins.	. . .	s.	. . .
Methacetin,	530	0.8	s.	. . .
Methylal.	3	152	s.	. . .
Methyl Chloride,	4 vol.	. . .	35 vol.	. . .
Methylene (Blue),	s. s.	. . .	s.	. . .
" Chloride,	s. s.	. . .	s.	. . .
Microcidin,	3	152	. . .	. . .
Monobromphenol,	sp.	. . .	s.	. . .
Monochlorphenol,	sp.	. . .	s.	. . .
Morphine,	v. sp.	. . .	100	3.7
" Acetate,	12	38	68	5.5
" Hydrochlorate,	24	19	63	5.9
" Sulphate,	24	19	702	0.5
Naphthalene,	1000	0.4	s.	. . .
Naphtol,	1000	0.4	s.	. . .
Neurodin,	s. s.	. . .	. . .	. . .
Oleocreosote,	ins.	. . .	s. s.	. . .
Orexin Hydrochlorate,	v. s.	. . .	v. s.	. . .
a-Oxynaphtoic Acid,	ins.	. . .	10	37.4
Paraformic Aldehyde,	s.	. . .	s.	. . .
Paraldehyde,	10	45.6	s.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.
Pental,	ins.	. . .	v. s.	. . .
Phenacetin,	ins.	. . .	s. s.	. . .
Phenocoll Acetate,	3.5	130.2	. . .	. . .
" Carbonate,	ins.	. . .	. . .	. . .
" Hydrochlorate,	16	28.5	. . .	. . .
" Salicylate,	s.	. . .	. . .	. . .
Phosphorus,	ins.	. . .	v. sp.	. . .
Physostigmine Salicylate,	130	3.5	12	31.1
Picrotoxine,	150	30.4	10	37.4
Pilocarpine Hydrochlorate,	v. s.	. . .	v. s.	. . .
Piperazine,	v. s.	. . .	. . .	. . .
Piperine,	alm. ins.	. . .	30	12.4
Plumbic Acetate,	1.8	253.3	8	46.7
" Carbonate,	ins.	. . .	ins.	. . .
" Iodide,	2000	0.2	v. sp.	. . .
" Nitrate,	2	228	alm. ins.	. . .
" Oxide,	ins.	. . .	ins.	. . .
Potassium Hydrate,	0.5	912	2	187
" Acetate,	0.4	1140	2.5	149.6
" Bicarbonate,	3.2	142.5	alm. ins.	. . .
" Bichromate,	10	45.6	ins.	. . .
" Bitartrate,	210	2.1	v. sp.	. . .
" Bromide,	1.6	285	200	1.8
" Carbonate,	1	456	ins.	. . .
" Chlorate,	16.5	27.6	v. sp.	. . .
" Citrate,	0.6	760	v. sp.	. . .
" Cyanide,	2	228	sp.	. . .
" and Sodium Tartrate,	2.5	182.4	alm. ins.	. . .
" Ferrocyanide,	4	114	ins.	. . .
" Hypophosphite,	0.6	760	7.3	51
" Iodide,	0.8	570	18	20.7
" Nitrate,	4	114	alm. ins.	. . .
" Permanganate,	20	22.8	dec.	. . .
" Sozoiodol,	50	9.12	. . .	. . .
" Sulphate,	9	50.6	ins.	. . .
" Sulphite,	4	114	sp.	. . .
" Tartrate,	0.7	651.4	alm. ins.	. . .
Pyoctanin Blue (Methyl-violet),	50 (?)	. . .	. . .	. . .
Pyridin,	. . .	. . .	1	374
Pyrocatechin,	s.	. . .	s.	. . .
Quinidine Sulphate,	100	4.5	8	46.7

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F. or 15° C. grs. pr. f℥
Quinine,	1600	0.2	6	62.3
" Bisulphate,	10	45.6	32	11.6
" Hydrobromate,	16	28.5	3	124.6
" Hydrochlorate,	34	13.4	3	124.6
" Sulphate,	740	0.6	65	5.7
" Valerianate,	100	4.5	5	74.8
Resopyrin,	ins.	. . .	5	75
Resorcin,	2	228	s.	. . .
Sugar, Cane,	0.5	912	175	2.1
" Milk,	7	65.1	ins.	. . .
Saccharin,	400	1.14	30	124.6
Salacetol,	ins.	. . .	15	30.4
Salicylamid,	250	1.82	s.	. . .
Salipyrin,	s. s.	. . .	s.	. . .
Salocoll,	200	2.28	s.	. . .
Salol,	ins.	. . .	10	37.4
Salophen,	ins.	. . .	v. s.	. . .
Salicin,	28	16.2	30	12.4
Santonin,	alm. ins.	. . .	40	9.3
Silver Cyanide,	ins.	. . .	ins.	. . .
" Iodide,	ins.	. . .	ins.	. . .
" Nitrate,	0.8	570	26	17.5
" Nitrate (fused),	0.6	760	25	18.24
" Oxide,	v. sp.	. . .	ins.	. . .
Sodium Hydroxide,	1.7	268.2	v. s.	. . .
" Acetate,	3	152	30	12.4
" Arsenate,	4	114	v. sp.	. . .
" Benzoate,	1.8	253.3	45	8.3
" Bicarbonate,	12	38	ins.	. . .
" Bisulphite.	4	114	72	5.2
" Borate (Borax),	16	28.5	ins.	. . .
" Bromide,	1.2	380	13	28.7
" Carbonate,	1.6	285	ins.	. . .
" Chlorate,	1.1	414.5	40	9.3
" Chloride,	2.8	162.8	alm. ins.	. . .
" Hypophosphite,	1	456	30	12.4
" Hyposulphite,	1.5	304	ins.	. . .
" Iodide,	0.6	760	1.8	207
" Nitrate,	1.3	350.7	sp.	. . .
" Paracresotate,	. . .	. . .	. . .	. . .
" Phosphate,	6	76	ins.	. . .
" Pyrophosphate,	12	38	ins.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL. (*Continued.*)

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. grs. pr. f℥j.
Sodium Salicylate,	1.5	304	6	62.3
" Santoninate,	3	152	12	31.1
" Sozoiodol,	14	32.5	. . .	. . .
" Sulphate,	2.8	162.8	ins.	. . .
" Sulphite,	4	114	sp.	. . .
" Sulphocarbolate,	5	91.2	132	2.8
Sozal,	s.	. . .	s. s.	. . .
Sozoiodol,	s.	. . .	s.	. . .
Strychnine,	6700	0.06	110	3.4
" Sulphate,	10	45.6	60	6.2
Sulphaminol,	ins.	. . .	s.	. . .
Sulphonal,	450	1.01	65	5.8
Sulphosalicylic Acid,	s.	. . .	s.	. . .
Sulphur,	ins.	. . .	ins.	. . .
Symphorol L,	s.	. . .	alm. ins.	. . .
" N,	50	9.1	alm. ins.	. . .
" S,	s.	. . .	alm. ins.	. . .
Tetronal,	450	1.01	s.	. . .
Thallin Sulphate,	7	65.1	100	1.8
" Tartrate,	10	45.6	s. s.	. . .
Thermodin,	s.	. . .	. . .	. . .
Thioform,	ins.	. . .	ins.	. . .
Thiol,	s.	. . .	s.	. . .
Thiophen,	ins.	. . .	. . .	. . .
Thioresorcin,	. . .	. . .	s. s.	. . .
Thiosinamin,	s. s.	. . .	s.	. . .
Thiuret,	350	1.3	ins.	. . .
Thymacetin,	s. s.	. . .	. . .	. . .
Thymol,	1200	0.38	1	37.4
Trional,	320	1.4	s.	. . .
Urethan,	1	456	0.6	623
Uropherin,	s.	. . .	. . .	. . .
Veratrine,	v. sp.	. . .	3	124.6
Zinc Acetate,	3	152	30	12.4
" Bromide,	v. s.	. . .	v. s.	. . .
" Carbonate,	ins.	. . .	ins.	. . .
" Chloride,	v. s.	. . .	v. s.	. . .
" Iodide,	v. s.	. . .	v. s.	. . .
" Oxide,	ins.	. . .	ins.	. . .
" Phosphide,	ins.	. . .	ins.	. . .
" Sozoiodol,	20	22.8	s.	. . .
" Sulphate,	0.6	760	ins.	. . .
" Valerianate,	100	4.5	40	9.3

GLOSSARY

OF UNUSUAL CHEMICAL TERMS.

[The figures in parenthesis refer to the pages of this book, where a fuller explanation may be found.]

ACTINISM. The chemical effects of light.

Areometer. Hydrometer. (13.)

Ærugo. Verdigris. Impure subacetate of copper.

Æthiops. Black sulphide of mercury. Hg_2S.

Alabaster. A light-colored, compact gypsum $CaSO_4$. (261.)

Alchemy. The Arabic name for chemistry, which formerly arose out of the search for the philospher's stone and the elixir of life.

Alembic. A form of still or retort, used in sublimation.

Alkarsin. Oxide of cakodyl, or cacodylic acid. $As(CH_3)_2O_2H$.

Alloy. A mixture or compound formed by fusing two or more metals together.

Amidon. Starch. (367.)

Amorphous. Without a definite crystalline form.

Anhydride. An oxide which can combine with the elements of water to produce an acid. Hence, an acid deprived of one or more molecules of water.

Anode. The + pole of a voltaic circuit.

Apple Oil. Valerianate of amyl.

Aqua Fontana. Aqua, U. S. P.

Aqua Fortis. Crude nitric acid. (176.)

Aqua Phagedænica. Yellow wash. Mercuric hydrate.

Aqua Regia. Nitro-muriatic acid. (176.)

Aqua Vitæ. Brandy.

Argols. Crude cream of Tartar. (243.)

Arrack. A spirituous drink made from the juice of the cocoanut tree.

Auripigmentum. Orpiment. Arsenous sulphide.

Austral. The south pole of a magnet.

Azote. (Fr.) Nitrogen.

Azotic Acid. Nitric acid. (176.)

BALDWIN'S Phosphorus. Fused calcium nitrate; possibly luminous calcium sulphide.

Balsam of Sulphur. A solution of S. in olive oil.

Barilla. The ashes of sea plants, and **Salsola Soda.**

Basyl. A term applied to an electro-positive radical.

Battery. An apparatus for the production of electricity by chemical action. (62.)

Baumé. The name of the inventor of a hydrometer bearing this name.

Bell Metal. An alloy of 6 parts copper and 2 parts tin.

Bestuchuf's Tincture. An ethereal solution of Fe_2Cl_6.

Bibron's Antidote. A solution of $HgCl_2$,KI, bromine, alcohol, and water.

Bittern. The mother liquor remaining after extracting NaCl from sea water by evaporation and crystallization.

Black Ash. Impure Na_2CO_3, mixed with carbon.

Black Drop. Acetum opii. Vinegar of opium.

Black Flux. Made by igniting cream of tartar with one-half its weight of nitre, KNO_3. It contains carbon and K_2CO_3.

Black Lead. Plumbago; a native variety of carbon, used for making lead pencils, crucibles, and stove polish. (202.)

Black Salts. The ley of wood-ashes evaporated nearly to dryness.

Black Wash. Contains suboxide of mercury, Hg_2O. (275.)

Bleaching Powder. Chloride of lime. A mixture of chloride and hypochlorite of calcium. (259.)

Blende Native sulphide of zinc. ZnS. (272.)

Blue Mass. Pilulæ Hydrargyri.

Blue Ointment. Unguentum Hydrargyri.

Blue Vitriol, or Bluestone. Sulphate of copper. (250.)

Bole. An argillaceous earth.

Bone Ash. Impure Ca_3PO_4 from burning bones. **Bone-black.** (Charred bones.) 203.

Borax. Biborate of sodium. Tetraborate of sodium, $Na_2B_4O_7$. (234.)

Boreal. The north pole of a magnetic needle.

Brass. An alloy of copper and zinc.

Brimstone. Roll sulphur. (153.)

British Barilla. Black Ash.

British Gum. Dextrin. (369.)

Bronze. An alloy of copper and tin.

Brunswick Green. Oxychloride of copper.

Bunsen Burner. A gas burner used for the production of heat. It mixes the gas and air before burning them.

Burnett's Disinfecting Fluid. Solution of $ZnCl_2$. (167.)

Butter of Zinc, Antimony and Bismuth. Their chlorides.

CALAMINE. Impure, native carbonate of zinc. (270.)

Calcareous Spar. Calcite. $CaCo_3$. (262.)

Calcedony. A native form of SiO_2.

Calcined Mercury. Mercuric Oxide. HgO.

Calcining. Igniting a substance in the air, so as to burn off any oxidizable material, or expel volatile products.

Calomel. Mercurous chloride. Mild chloride of mercury, Hg_2Cl_2. (275.)

Caloric. Old term for heat.

Calorie. The unit of heat used in determining the heat of combination of chemical compounds. (29.)

Camphene. Oil of turpentine. Camphene burning fluid is a solution of turpentine in alcohol.

Canton's Phosphorus. Luminous CaS, or luminous paint.

Caput Mortuum. The residue left after ignition of $FeSO_4$ or iron pyrites. Impure Fe_2O_3. (295.)

Caramel. Burnt sugar. (363.)

Carbolic Acid. Phenic acid. Phenyl acohol. (426.)

Carburet. Carbide.

Catalysis. The action of a body in promoting combination or decomposition by its presence, the body itself remaining unchanged.

Cathode. The negative pole of a galvanic circuit.

Chalk. An amorphous carbonate of lime. (262.)

Chameleon Mineral. Permanganate of potassium.

Choke Damp. Carbonic anhydride. CO_2. (212.)

Chrome Green. A mixture of chrome yellow and Prussian blue; or sesquioxide of chromium. Cr_2O_3. (285.)

Chrome Vermilion. Dichromate of lead. $PbCr_2O_7$.

Chrome Yellow. Chromate of lead. $PbCrO_4$. (224.)

Cinnabar. Native red sulphide of mercury. HgS. (274.)

Citrine Ointment. Nitrate of mercury ointment.

Clay. Impure silicate of alumina.

Clay Ironstone. A variety of hematite iron ore. Fe_2O_3.

Colcothar. Ferric oxide. Fe_2O_3. Rouge; crocus.

Collodion. Solution of gun cotton in alcohol and ether. (370.)

Colloids. Jelly-like or non-crystallizable bodies. (76.)

Colophony. Common resin, or rosin. (323.)

Common Salt. Sodium Chloride. $NaCl$. (228.)

Condy's Solution. Contains permanganate of potassium. $K_2Mn_2O_8$. (290.)

Copperas. Green vitriol. Crystallized ferrous sulphate. $FeSO_4 . 7Aq$. (293.)

Corrosive Sublimate. Mercuric chloride. Bichloride of mercury. (277.) $HgCl_2$.

Cream of Tartar. Acid potassium tartrate. $HKC_4H_4O_6$. (243.)

Crocus of Antimony, or Crocus Metallorum. Oxysulphide of antimony. (197.)

Crocus Martis. Colcothar. Fe_2O_3

Crystalloids. Crystallizable bodies, as distinguished from colloids. (76.)

Crystals of Venus. Copper acetate. $Cu(C_2H_3O_2)_2.H_2O$.

Cubic Nitre. Sodium nitrate. $NaNO_3$

Cupellation. The process of purifying silver or gold in a **cupel** or cup made of bone ash. When the alloy is strongly heated in the air, the other metals oxidize, and the cupel absorbs the oxide, leaving the pure silver or gold.

DECANTATION. The process of pouring off the clear liquid above a sediment.

Decoction. An extract of an organic substance, made with boiling water.

Decrepitation. The crackling of certain salts when suddenly heated.

Deflagration. A rapid and scintillating combustion. It takes place in certain mixtures containing the nitrates or chlorates.

Delequescent. An adjective applied to those substances which attract moisture from the air and liquefy. (77.)

Destructive Distillation. Dry distillation, conducted with the object of destroying the substance and producing new ones. (27.)

Detonation. Rapid chemical action, accompanied by flame and noise. An explosion

De Valangin's Arsenical Solution. A solution of the chloride. $AsCl_3$. **Liq. Arsen. Hydrochlor.**

Dew-point. The temperature at which the moisture of the air begins to deposit.

Dialysis. The process of the diffusion of liquids and solutions through membranes. (75.)

Dimorphous. Crystallizing in two distinct systems. (76.)

Displacement. Expelling a fluid from a vessel by another c different density.

Dolomite. Magnesium limestone. (267.)

Donovan's Solution. Contains the iodides of arsenic an mercury. (186.)

Dover's Powder. Compound ipecac. powder; contains opiu (1 gr. in 10.)

Drummond Light. Calcium light.

Dry Distillation. The process of subjecting solid or organ bodies to heat, in a closed retort.

Ductile. Capable of being drawn into wire, or rolled out int sheets.

Dutch Gold. A species of brass, usually sold in very thi leaves or sheets.

Dutch Liquid. Ethene dichloride. $C_2H_4Cl_2$.

Dutch White. Impure white lead.

EAU de Javelle. A solution of chlorinated potass. or p tass. hypochlorite. KOCl.

Educts. The proximate principles of which bodies were fo merly supposed to be formed.

Effervescence. The rapid escape of gas from a liquid.

Efflorescence. The escape of the water of crystallization an the consequent crumbling down of the crystal. (77.)

Electrode. The pole or wire forming a part of a voltaic ci cuit. (65.)

Electrolysis. Decomposition by means of a strong electr current. (71.)

Element. A substance which has never been decomposed.

Elixir of Vitriol. Aromatic sulphuric acid.

Elutriation. The process of separating the finer and light particles of a powder from the coarser, by suspending them i water and pouring off the lighter floating particles with th water.

Emerald Green. Schweinfurth green, or aceto-arsenite copper. See Paris green.

Emery. An impure corundum. Al_2O_3. (283.)

Eosin. Tetrabrom-fluorescine. A beautiful, red, artifici coloring matter.

Epsom Salt. $MgSO_4.7Aq$. (265.)

Eremacausis. The slow decay of organic substances in th air.

Essence of Mirbane. Nitro-benzol. (528.)

Essential Oils. Volatile oils.

Eudiometer. A graduated glass tube, closed at one end, used for measuring gases.

FERMENTATION. (542.)

Filter. A porous substance used to separate a solid and liquid by allowing the latter to pass through, while the former is retained.

Fire Damp. Light carbureted hydrogen (Marsh gas), mixed with air. (315.)

Fixed Air. Choke damp. CO_2. (164.)

Flint. An impure variety of silica. SiO_2.

Flowers of Antimony. Oxide of antimony.

Flowers of Benzoin. Benzoic acid. (437.)

Flowers of Sulphur. Sulphur sublimatum. U. S. P. (153.)

Flowers of Zinc. Oxide of zinc. ZnO. (272.)

Fluorescence. The property possessed by certain bodies, as quinine salts, of rendering visible the ultra-violet or chemical rays of the solar spectrum.

Fluor Spar. Native calcium fluoride. CaF_2 (115.)

Flux. A material added to ores in smelting, to form an easily fusible slag.

Foliated Earth of Tartar. $KC_2H_3O_2$. Potassium acetate.

Fool's Gold. Iron pyrites.

Fowler's Solution. Solution of the arsenite of potassium. (185.)

French Chalk. Silicate of magnesia. Soapstone; talc.

Fructose. Fruit sugar. Levulose.

Fuchsine. Aniline red. Magenta. $C_{20}H_{19}N_3$.

Fuming Liquor of Libarius. Solution of stannic chloride.

Fusel Oil. Amylic alcohol. (351.)

Fusible Calculus. One composed of a mixture of phosphate of lime, and ammonia-magnesium phosphate.

Fusible Metal. Bismuth 2 parts, lead 1 part, and tin 1 part. Melts at about 200° F.

GALENA. Native lead sulphide. (220.)

Galvano-Cautery. A surgical knife heated by galvanic current.

German Silver. An alloy of copper, nickel, and zinc.

Glass. An artificial silicate of calcium, sodium, iron, lead, etc.

Glass of Antimony. Fused trisulphide of antimony. Sb_2S_3.

Glass of Borax. Fused Borax.

Glauber's Salt. Sodium sulphate. (230.)

Glucose. Grape sugar. Now made on large scale from corn starch (359.)

Glucoside. (See p. 492.)

Glyceroles and Glycerita. Simple glycerin solutions.

Goniometer. An instrument for measuring the angles of crystals.

Goulard's Extract, and Cerate. Contain subacetate of lead.

Graphine. Carbon deposited in gas retorts.

Graphite. Plumbago. Black lead. (202.)

Green Vitriol. Copperas. $FeSO_4.7Aq.$ (293.)

Guano. A deposit of excrement of sea fowl.

Gypsum. Calcium sulphate. Plaster-of-Paris. (261.)

HALOGEN Elements. Haloid Salt. The elements of the chlorine group and their binary compounds. (186.)

Harle's Solution. Solution of arsenite of sodium.

Hartshorn. Ammonia. (169.)

Haschisch. Indian hemp.

Hepar Sulphuris. Liver of sulphur. Potassium sulphide.

Hive Syrup. Compound syrup of squills.

Hoffman's Anodyne. Spirit. Æther. Co. Ether, 1 pint; alcohol, 1 pint; ethereal oil, f℥vj.

Homberg's Pyrophyrus. Is made by igniting potassium, alum and charcoal.

Homologous Series. (310.)

Homologues. (311.)

Huxham's Tincture. Compound tincture of cinchona.

Hydracid. A binary acid. Contains no oxygen.

Hydrate. A compound containing hydroxyl, HO, combined to a positive radical.

Hydrochloride. A compound of HCl, formed by the union of the whole molecule by synthesis; as compounds with the alkaloids.

Hydroxide. Same as a hydrate.

Hygrometer. An instrument for the determination of the relative amount of moisture in the air.

ICE Vinegar. Glacial acetic acid. (411.)

Incandescence. The glow of a highly heated body.

Incineration. The reduction of a substance to ashes by burning.

Incompatible. Incapable of being mixed without chemical change.

Infusion. An extract of an organic substance, made by pouring hot water upon it and allowing it to stand for some hours. (149.)

Inosite. Muscle sugar. (361.)

Ion. A body going to the positive (anode) or negative (cathode) pole of a galvanic battery during electrolysis.

Iron Pyrites. Native sulphide of iron. Fool's gold.

Isinglass. A variety of gelatin, or fish glue. Sometimes erroneously applied to mica.

Ivory Black. Animal charcoal, made by distilling ivory scraps; is now generally applied to bone black.

JAMES' Powder. Antimonial powder.

Japan Black. A varnish composed of asphaltum, turpentine, linseed oil, and umber.

Jesuits' Powder. Powdered cinchona bark.

KAOLIN. A pure white clay.

Kelp. Ashes of sea weeds; used as a source of iodine and carbonate of sodium.

Kermes' Mineral. Sb_2S_3. (197.)

King's Yellow. Orpiment. As_2S_3.

Kyan's Disinfectant. Solution of $HgCl_2$.

LABARRAQUE'S Disinfecting Liquid. Solution of hypochlorite of sodium or chlorinated soda. (234.) (168.)

Lac Sulphuris. Precipitated sulphur. (154.)

Lacquer. A varnish used for brass, etc.

Lactin—Lactose. Sugar of milk. (364.)

Lady Webster Pill. Pill of aloes.

Lake. An organic coloring matter precipitated with aluminum hydrate. Used as pigments.

Lampblack. The soot of burning turpentine. (203.)

Lana Philosophica. Oxide of zinc. (272.)

Lapis Infernalis. Lunar caustic. $AgNO_3$.

Laughing Gas. Nitrous oxide. N_2O. Dentists' gas. (171.)

Lead Water. Diluted Goulard's Extract, containing subacetate of lead. (224.)

Ledoyen's Disinfecting Liquid. Solution of nitrate of lead. (167.)

Levigation. The reduction of a substance to an impalpable powder, by rubbing on a slab with a flat pestle called a muller, with sufficient water to form a paste.

Lime. CaO. (260.)

Limestone. A native carbonate of lime. (258.)

Litharge. PbO. Semi-vitrified oxide of lead. (222.)

Lithic Acid. Uric Acid. (458.)

Liver of Sulphur. Potass. sulphuret. K_2S. (242.)

Lixiviation. The separation of the soluble portions of a substance by causing water to filter through it. (149.)

Loadstone. The native magnetic oxide of iron, or magnetite. A magnet. (295.)

Lugol's Solution. Compound solution of iodine. Iodine held in solution by Ki. (124.)

Lunar Caustic. Nitrate of silver. $AgNo_3$. (255.)

Lute. An adhesive mixture for closing the joints of apparatus, to prevent the escape of vapors, etc.

MACERATION. The long-continued soaking of a substance in water at common temperatures. (149.)

Macquer's Salt. Potassium arsenate.

Magendie's Solution. Morph. sulphate, gr. xvj; water, f℥j.

Magistery of Bismuth. Subnitrate.

Magma A pasty mass.

Magnesia Alba. Magnesium carbonate. (270.)

Malleable. Capable of being worked under the hammer.

Marble. Nearly pure native carbonate of lime. (262.)

Marine Acid. Muriatic acid. Hydrochloric acid. HCl. (119.)

Martial Æthiops. Fe_3O_4. Magnetic oxide of iron.

Massicot. Amorphous oxide of lead. PbO. Powdered litharge. (222.)

Matrass. A glass vessel with a long neck, or a tube sealed at one end. Used for heating dry substances.

Menstruum. A solvent, or medium of chemical reaction.

Mercaptan. An alcohol in which O is replaced by sulphur.

Metalloid. Non-metal. (106.)

Metameric Bodies. The same as isomeric. (313.)

Microcosmic Salt. $NaNH_4HPO_4$.

Milk of Lime. Whitewash. (261.)

Milk of Sulphur. Precipitated sulphur.

Mineral Water. Water charged with carbonic acid; also natural water holding medicinal substances in solution. (148.)

Mineral Yellow. Oxychloride of lead.

Minium. Red oxide of lead. $2PbO.PbO_2$. (222.)

Molecule. (79.)

Monsel's Salt. Subsulphate of iron. (296.)

Mordant. A substance used to fix colors on fabrics.

Mosaic Gold. Brass.

Mountain Blue. Azurite. Native basic carbonate of copper.

Mountain Green. Malachite. A native basic carbonate of copper. (251.)

Mulberry Calculus. Calcium oxalate. CaC_2O_4.

Muriate. A chloride.

Muriatic Acid. Hydrochloric acid. (119.)

NAPHTHA. A light hydrocarbon obtained from petroleum, and boiling at about 80° to 105° C. (332.)

Natron. Native carbonate of sodium.

Neutral. Without action on test paper. Neither acid nor alkaline.

Neutral Mixture. Solution of citrate of potassium.

Nitre. Saltpetre. KNO_3. (240.)

Normal Salt. Neither acid nor basic.

OBSIDIAN. Volcanic glass.

Ochre. A native mixture of clay and ferric oxide, used as a paint.

Oil of Vitriol. H_2SO_4. Sulphuric acid. (158.)

Oil of Wine Ethyl sulphate. $(C_2H_5)_2SO_4$.

Oreide. A species of brass resembling gold, and used for jewelry.

Orpiment. Arsenous sulphide. As_2S_3. (185.)

Ortho-acid. An acid in which each bond of the kernel is united to hydroxyl. (OH)

Osmosis. The diffusion of liquids through porous septa. See Dialysis. (75.)

Ox-acid. A ternary acid containing oxygen.

PACKFONG. A variety of German silver.

Paris Green. Impure Schweinfurth green. Aceto-arsenite of copper. (251.)

Particle A minute portion of matter.

Pearl Ash. Impure carbonate of potassium. (241.)

Pearl Powder. Subnitrate, or oxychloride of bismuth. ($BiONO_3$ or $BiOCl$.)

Pearl White. $BiONO_3$, or $BiOCl$.

Pearson's Salt. Arsenate of sodium. Na_3AsO_4.

Pewter. An alloy of variable composition. Usually composed of tin, lead, copper, and antimony, or zinc.

Pinchbeck Gold. A species of brass.

Plaster-of-Paris. Calcium sulphate. Calcined gypsum. (261.)

Platinum Black, and Sponge. Finely divided platinum. (299.)

Plumbago. Native carbon. Graphite. (202.)

Potash. Impure carbonate of potassium.

Potassa. Oxide or hydrate of potassium.

Powder of Algaroth. Oxychloride of antimony. (196.)

Precipitate. An insoluble substance formed on bringing two or more substances together in solution.

Precipitatum Per Se Mercuric oxide. HgO. Made by heating mercury to near its boiling point until it oxidizes.

Preston Salts. Carbonate of ammonia, flavored with some essential oil

Prussian Blue. Ferric ferrocyanide. (217.)

Prussic Acid Hydrocyanic acid. (528.)

Pseudomorph. A mineral crystallized in the form that belongs to another mineral.

Puce-oxide of Lead. Lead peroxide, or brown oxide.

Purgative Mineral Water. Liq. Magnes. citrat.

Purple of Cassius. A pigment produced by treating chloride of gold with a solution of stannous chloride. (257.)

Putty. Composed of whiting and Linseed oil.

Putty Powder. Stannic oxide.

Pyrites. Native sulphide of iron.

Pyroxilic Spirit. Wood alcohol. Methyl alcohol. (345.)

Pyroxylin Gun cotton. Trinitro-cellulose. (370.)

QUANTIVALENCE. Quantity of combining power; applied to atoms. (See Equivalence.)

Quartz. SiO_2. (217.)

Quevenne's Iron Ferrum redactum. (292.)

Quicklime. Caustic lime. CaO. (260.)

Quicksilver. Mercury. (274.)

RADICAL. An atom, or group of atoms, forming the basis of a series of compounds. (90.)

Radical Vinegar. Glacial acetic acid.

Realgar. Red sulphide of arsenic. (187.)

Red Precipitate. Red oxide of mercury. HgO. (279.)

Red Prussiate of Potash. Ferricyanide of potassium. (217.)

Red Tartar. Argol (422.)

Regulus of Antimony. Metallic antimony.

Roche, and Roman Alums. Are varieties of potassium alum.

Rochelle Salt. Tartrate of potassium and sodium. (244.)

Rock Crystal. Quartz SiO_2. (217.)

Roman Vitriol. Sulphate of copper $CuSO_4$.

Rouge Ferric oxide in fine powder. Fe_2O_3.

Ruby. Native Al_2O_3, of a beautiful red color (283.)

Rust. Ferric oxide; generally containing some ferric hydrate.

SACCHARUM Saturni. Acetate of lead (224.)

Safety Lamp. A lamp inclosed in wire gauze, to prevent explosions of explosive gases in mines, cellars, etc.

Sal Æratus. Potassium bicarbonate.

Sal Alembroth. Double chloride of mercury and ammonium. (276.)

Sal Ammoniac. Ammonium chloride. (245.)

Sal Diureticus Potassium acetate.

Sal Enixum. Potassium bisulphate.

Sal Mirabile. Sodium sulphate.

Sal Perlatum. Sodium phosphate.

Sal Prunelle. Fused nitre. KNO_3.

Sal Volatile. Ammonium carbonate.

Salt of Lemon and Salt of Sorrell. Potassium binoxalate. (243.)

Salt of Phosphorus. Microcosmic salt.

Salt of Saturn. Acetate of lead. (224.)

Salt of Tartar. Pure potassium carbonate. (241.)

Saltpetre. Potassium nitrate. (240.)

Sapphire. A native form of Al_2O_3, of a blue color. (283.)

Scheele's Green. Arsenite of copper. (188.)

Schlippe's Salt. Sodium sulphantimoniate. Na_3SbS_4.

Schweinfurth Green. Copper aceto-arsenite. (251.)

Seidlitz Powder. A mixture of sodium bicarbonate and Rochelle salt in one paper and tartaric acid in another.

Seignette's Salt. Rochelle salt, $KNaC_4H_4O_6$. (244.)

Sienna. A native red pigment. An impure oxide of iron.

Sizing. A gelatinous mixture put into paper or cloth, to fill up the pores.

Slag. The fused impurities from smelting of ores. (292.)

Smalt. Glass colored blue by oxide of cobalt and powdered.

Smelting. The process of recovering the metals from their ores.

Soapstone. Talc. (268)

Soda Ash. Crude sodium carbonate. (232.)

Soda Saltpetre. Sodium nitrite. $NaNO_3$. (234.)

Soda Water. Water artificially charged with CO_2 under pressure.

Solder. An alloy of tin and lead.

Soluble Glass. See Water Glass. (218.)

Soluble Tartar. Neutral potassium tartrate. (243.)

Speculum Metal. An alloy of copper and tin.

Speiss. Impure, fused nickel arsenide.

Spelter. Commercial zinc.

Spermaceti. A fat obtained from the sperm whale

Spirit of Hartshorn. Spirit of ammonia. Solution of ammonia in alcohol.

Spirit of Mindererus. Solution of ammonium acetate. (247.)

Spirits of Nitre. Nitric acid. (378.)

Spirit of Salt. Muriatic acid. (119.)

Spirit of Wine. Alcohol.

Steinbuhl Yellow. Barium chromate. $BaCrO_4$.

Substitution. The displacement of an atom in a molecule by another atom of a different kind.

Sugar of Lead. Lead acetate. (224.)

Sulphuret. Sulphide.

Sulphuric Æther. Ethylic ether. $C_4H_{10}O$. (375.)

Sulphur Vinum. Impure sulphur. Horse brimstone.

TALMI Gold. An alloy of copper and aluminium.

Tartar Emetic. Antimonyl potassium tartrate. (244.)

Tasteless Purging Salt. Sodium phosphate.

Thenard's Blue. A compound of the oxides of aluminium and cobalt.

Tincal. Native borax. $Na_2B_4O_7$. (231.)

Tincture. A solution in alcohol. When in ether it is called an ethereal tincture.

Tombac. A kind of brass.

Tournesol. Litmus.

Trituration. Rubbing in a mortar.

Trona. Native sodium carbonate.

Tully's Powder. Compound morphine powder.

Turnbull's Blue. Ferrous ferricyanide. (217.)
Turner's Cerate. Calamine cerate.
Turner's Yellow. Lead oxychloride.
Turpeth Mineral. Yellow sulphate of mercury. (280.)
Tutty. Impure zinc oxide.
Type Metal. An alloy of lead and antimony. (195.)

ULTRAMARINE. Lapis lazuli. A compound of aluminum sodium silicate with sodium sulphide. A beautiful blue pigment. It is now prepared artificially, as well as a green, red, and violet variety.
Umber. A native silicate of aluminum, with oxides of iron and manganese. Used as a brown paint.

VALENCE of Atoms. Quantity of combining power. (87.)
Vallet's Mass. $FeCO_3$ made into a pill mass.
Varec. Kelp Ash of sea weeds.
Verd Antique. Precious serpentine.
Verdigris. Impure copper subacetate. (251.)
Verditer. Basic copper carbonate.
Vermilion. Artificial mercuric sulphide. HgS. (280.)
Vitriolic Acid. Sulphuric acid. (158.)

WATER Glass. Soluble glass. Sodium silicate. (218)
White Arsenic Arsenous oxide.
White Lead. A basic lead carbonate. (223)
White Precipitate. Ammoniated mercury. Mercur-amidogen chloride. NH_2HgCl. (278.)
White Vitriol. Zinc sulphate. (272.)
Whiting. Prepared chalk. $CaCO_3$. White clay, often sold for whiting.
Wood Naphtha and Wood Spirit. Methyl alcohol. (345.)
Wood Vinegar. Pyroligneous acid. Impure acetic acid. (411.)

YELLOW Prussiate of Potash. Potassium ferrocyanide. (216.)
Yellow Wash. Made by adding corrosive sublimate to lime water. It forms mercuric oxide. (278.)

ZAFFRE Impure cobalt oxide.
Zinc White. Zinc oxide. Used as a paint. (272.)
Zymosis. The peculiar action caused by a ferment.

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Appendix.
Index.

The many special subjects considered in this volume demanded much expert knowledge; in order, therefore, that the statements made should be accurate, the authors have consulted with and received valuable help from various specialists in Architecture, Food Analysis, Chemistry, Heating, Ventilation, etc.

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